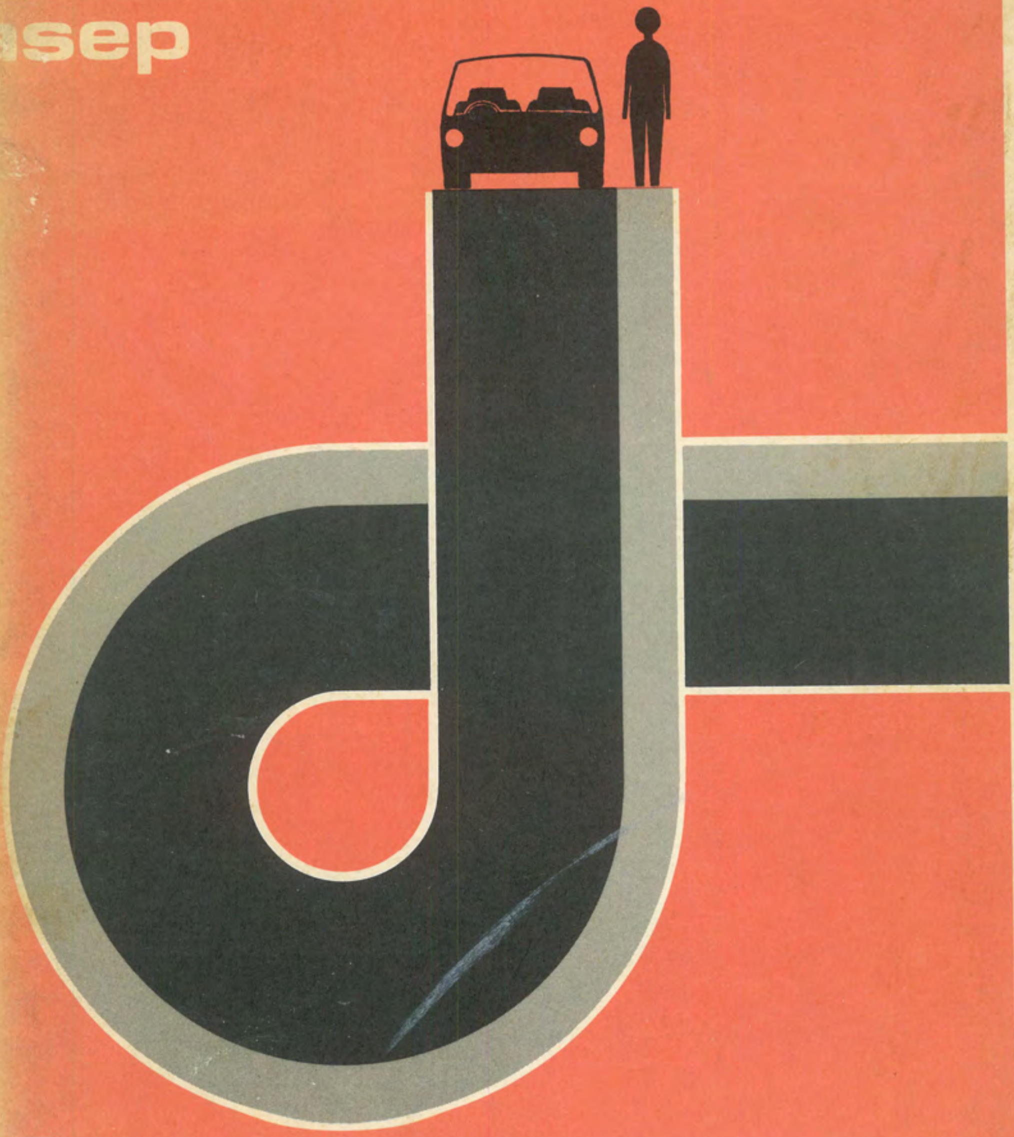
Traffic

asep

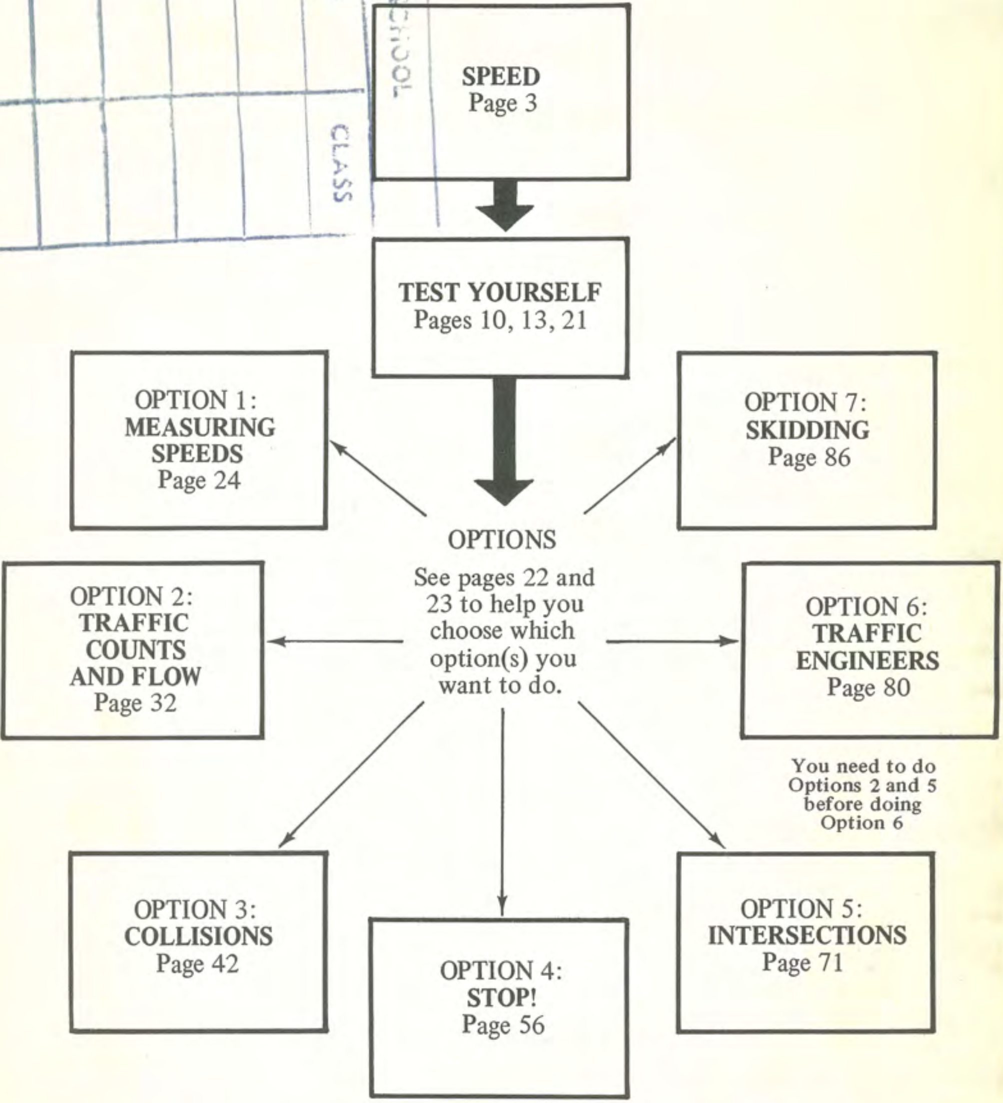


AUSTRALIAN SCIENCE EDUCATION PROJECT

DATE
HIGH SCHOOL
NAME
CLASS

This book contains information on how vehicles move and stop, and about traffic speed and flow. It also describes methods that you can use to measure these aspects of traffic.

PLAN


SPEED
Page 3
TEST YOURSELF
Pages 10, 13, 21
OPTIONS
See pages 22 and 23 to help you choose which option(s) you want to do.
OPTION 1: MEASURING SPEEDS
Page 24
OPTION 2: TRAFFIC COUNTS AND FLOW
Page 32
OPTION 3: COLLISIONS
Page 42
OPTION 4: STOP!
Page 56
OPTION 5: INTERSECTIONS
Page 71
OPTION 6: TRAFFIC ENGINEERS
Page 80
You need to do Options 2 and 5 before doing Option 6
OPTION 7: SKIDDING
Page 86

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7 You can record your results in your notebook in a table like the one below. Then try to answer the question: Which surface reduced the friction most?

SURFACE	DISTANCE TRAVELLED
SMOOTH	DO NOT WRITE IN THIS TABLE
WITH TALC	
WITH POLYSTYRENE BEADS	

8 'Super beads', used by hovercraft, are air molecules which are better than any of the friction-reducing substances you have tried.

☐ How far do you think your block could travel on 'super beads', if you could use them?

☐ How does air reduce friction for a hovercraft?

9 You should have enough information now to write an account of your investigation.

10 A hovercraft needs a constant force to keep it moving at a steady speed. Try to explain this.

SUMMING UP

☐ To start an object moving a force (push) is needed. An opposing force such as friction slows down a moving object.

☐ Without friction or other forces acting on it a moving object would keep going at the same speed for ever. Its speed would not change.

FINDING AVERAGE SPEEDS IN EVERYDAY LIFE

You should now have some idea how to measure average speed.

Discuss with a teacher which speed you want to measure and whether it is safe to do so. Here are some suggestions.

Cars

If you are near a busy road and can get permission, you could find the average speed of passing cars. If you think you'd like to do that, you could check procedures in Option 1 (Measuring Speeds), page 24.

Pedestrians

If you want to time some fellow students walking along a corridor, you can find out about that in Option 1, too–see Activity 2 (Measuring Pedestrian Speeds), page 29. You may be able to work out a speed at which students should usually try to walk in the corridors at your school.

Athletes

If there is a sports meeting on, or some students are practising running, you could find average speeds of the athletes. You could comment on changes in the speeds during take-off, the main run and the end of a sprint.

Conversion Chart

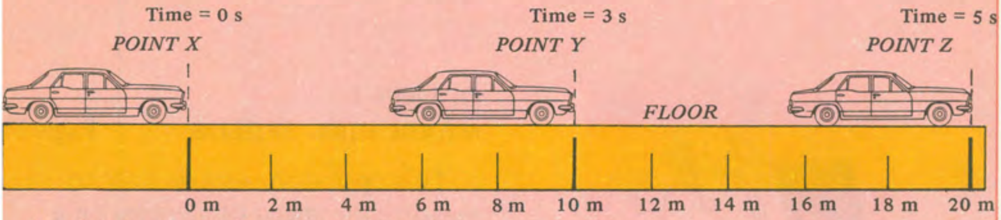
There is a conversion chart inside the back cover of this book to help you convert readings from one set of speed units to another. You will probably find this useful when makin notes about your investigations.

TEST YOURSELF–AVERAGE SPEEDS AND FORCES

Answer the following questions in your notebook.

Questions 16–19

A toy car began to move from point X on the floor of a corridor. Three seconds later the front of the car was at point Y. Five seconds after starting the front of the car was at point Z. The distances travelled are shown on the diagram below.



Read distances to the nearest metre.

16 How long did it take the toy car to travel from point Y to point Z?

17 How far did the car travel in moving from point Y to point Z?

18 What was the average speed of the car in travelling from point Y to point Z?

19 What was the average speed of the car in travelling from point X to point Z?

---

20 Which one of the following statements about the motion of an object and the force acting on the object is NOT correct?

A If there is no force acting on a moving object, it will gradually slow down.

B For a stationary object to start moving, it must be acted on by a force.

C A moving object must be acted on by a force in order to stop it moving.

D A force is necessary to make a moving object move faster.

21 If a car is travelling at a steady speed along a straight road, the force of the engine pushing the car forward is

A greater than all the resistance forces on the car.

B equal to all the resistance forces on the car.

C less than all the resistance forces on the car.

D greater than, equal to, or less than all the resistance forces on the car, depending on the speed of the car.

Now turn to Check Your Answers on page 102.

ABOUT THE OPTIONS

Here are summaries to help you decide which options to choose.

OPTION 1:
MEASURING SPEEDS . . . Page 24

This option shows you how to measure the speed of vehicles on a road and of pedestrians on a footpath or in a school.

OPTION 2:
TRAFFIC COUNTS AND FLOW . . . . Page 32

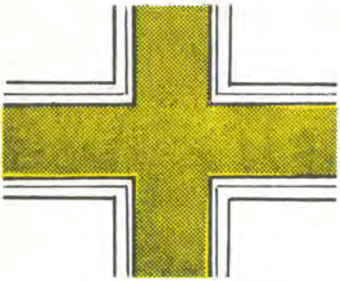
You can make sample counts of moving vehicles, and investigate traffic flow patterns which affect you.

OPTION 3:
COLLISIONS . . . . Page 4

Forces not only stop moving objects, but start them moving, too. These forces have effects on cars and drivers. (What is whip-lash injury?) There are some calculations for those who like mathematics.

OPTION 4:
STOP! . . . . Page 56

You measure your reaction time, and find out about the least stopping distance at a given speed. You may be able to design a safer car.



OPTION 5:
INTERSECTIONS . . . . Page 71

Intersections can cause traffic delays and accidents. This option shows you how to investigate ways in which delays may be reduced and safety increased.

OPTION 6:
TRAFFIC ENGINEERS . . . Page 80

You need to do Options 2 and 5 before doing Option 6.

This is an option about traffic engineers and the way some of them tackled a particular problem. It may help you to work out ways of investigating a traffic problem in your own area.

OPTION 7:
SKIDDING . . . . Page 86

Can a car stop quickly after a shower of rain? What happens if the rear wheels of a car lock on braking? You can use a cart to find answers to these and other questions.

OPTION

1

This option shows you ways of measuring vehicle and pedestrian speeds, and how to represent speeds on a distribution graph.

Measuring Speeds

In a traffic system, not all the people or all the vehicles move at the same speed.

On the road, there are fast drivers and slow drivers. On a footpath, some people walk slowly, while others are in a great hurry.

A knowledge of vehicle and pedestrian speeds is useful for the engineer planning roads. For example, pedestrian speeds can be used to decide how much time is needed for a group of pedestrians to cross a road, and the traffic lights can be set accordingly. If the speed at which trucks climb a hill is known, suitable passing lanes for cars can be built.

You may want to study an actual traffic situation. You could study road traffic, or pedestrian traffic on a footpath or perhaps in your school corridor. Activities 1 and 2 describe some methods that you could follow, although you may want to modify them, or think up others.

ACTIVITY 1: MEASURING VEHICULAR SPEEDS

Sometimes vehicles are timed over a measured distance. Here and on the next page are two ways you can do this. You will need to work with at least one partner, whatever way you do it.

METHOD 1: Choose two power poles (or other distinct objects) a suitable distance apart to mark the start and finish. When a vehicle passes the start, the partner there drops his arm. This is the signal to the partner at the finish to start timing with the stop-watch.

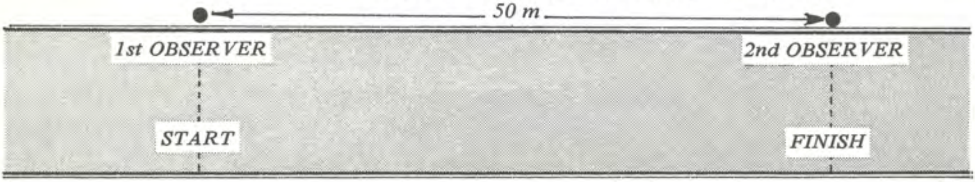
You will need (for either method):

- 1 tape-measure–to measure up to 50 m
- 1 stop-watch.

Timing

For timing, choose a straight section of the road where you can see the cars coming well before they reach you. Avoid places near traffic lights, intersections or shopping centres where there are likely to be traffic hold-ups.

Any distance can be used, but if the distance is too short, you may not be able to time cars accurately. If the distance is too long, it may be hard to see when a car crosses the start and finish of the measured distance. The diagram below shows a convenient distance, 50 metres.



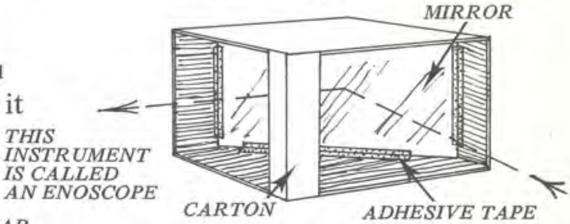
Activity 1 continued next page

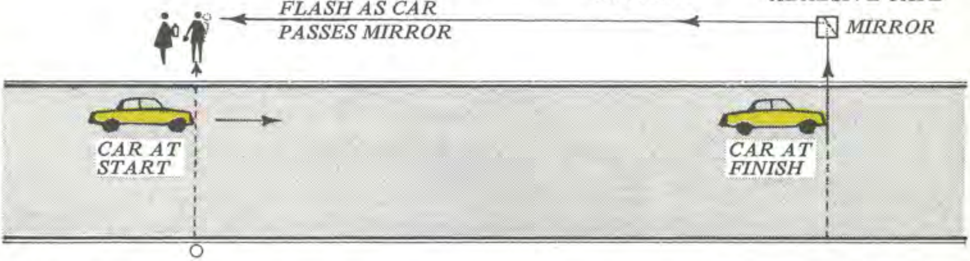
METHOD 2:

Use a mirror mounted in a box so that it can be set at 45° to the road. As the vehicle passes the start one partner can begin timing with the stop-watch. He then watches for the flash in the mirror as the vehicle passes the finish line. The other partner does the recording. If you want to use this method, practise it first.

If you use method 2, the mirror method, you will also need:

- 1 large mirror, about 20 cm × 30 cm
- 1 cardboard carton, about 30 cm × 20 cm × 20 cm
- adhesive tape.





You may be able to time every vehicle, but if there are too many you could 'sample' them. For example, you could time every second, or perhaps every fifth, vehicle.

This method will enable you to get results which represent fairly the traffic passing, i.e. a sample which isn't **biased**.

It may be best to time the vehicles in only one direction, if there is a lot of traffic. If there isn't much traffic, you could time the vehicles going both ways. If you do this, record your results for each way separately.

Thirty would be about the smallest sample from which you could get useful results. The more vehicles you time, the better your sample will be. On the other hand, it may be monotonous to time a large number of vehicles, and to calculate all their speeds.

You may want to share this task among several people. Working in groups of two or three should be satisfactory.

You can use the speed calculator on the back cover to convert your results to speeds.

RECORDING AND DISPLAYING VEHICLE SPEEDS

1.1 Design a sheet for recording all the information you collect. The one shown opposite was used by one group of students.

One way traffic engineers display information about vehicle speed is on a speed distribution graph. To plot the speed distribution of traffic, you need to time a fairly large number of vehicles. The information and the graph which shows it are on the opposite page.

TRAFFIC SPEED COUNT

DATE: 17 APRIL
DAY: TUESDAY
TIME: 1 P.M.

LOCATION: TOORAK ROAD, MALVERN
DIRECTION OF TRAVEL: EAST
MEASURED DISTANCE: (d): 50 METRES

OBSERVERS:
R.SHEPHERD
I.MARTIN

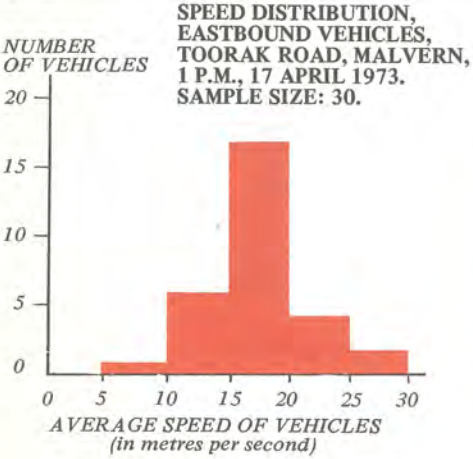
TIME in seconds	**SPEED** in metres* per second	**TIME** in seconds	**SPEED** in metres* per second	**TIME** in seconds	**SPEED** in metres* per second
3.0	17	4.6	11	1.9	28
3.6	14	3.0	17	2.7	19
1.9	28	2.8	18	3.1	17
3.0	17	5.2	9	3.1	17
2.7	19	2.4	21	3.5	15
2.9	18	2.0	25	3.4	15
2.4	21	3.0	17	2.6	19
2.5	20	3.0	17	2.4	21
3.7	14	3.0	17	3.0	17
3.2	16	4.4	12	2.6	19

* To the nearest whole number.

SPEED BANDS	**NUMBER OF VEHICLES WITH SPEEDS IN THAT BAND**
0 m/s to 5 m/s	0
6 m/s to 10 m/s	1
11 m/s to 15 m/s	6
16 m/s to 20 m/s	17
21 m/s to 25 m/s	4
26 m/s to 30 m/s	2
Total:	30

The fastest speed the Malvern group recorded was 28 metres per second, and the slowest speed was 9 metres per second. All the speeds can be sorted out into groups, or 'speed bands' as shown at left.

Each band in a speed band table should be the same 'width'. Each 'width' in this table is 5 metres per second. If the bands are the same width, the number of vehicles and their speeds can be compared easily on a distribution graph like the one on this page.


SPEED DISTRIBUTION, EASTBOUND VEHICLES, TOORAK ROAD, MALVERN, 1 P.M., 17 APRIL 1973. SAMPLE SIZE: 30.

Some points to watch when constructing your distribution graph are:

☐ label the graph clearly, so that it explains itself, and

☐ make the bands stand out clearly.

Activity 1 continued next page

Generally, there is a **narrow** distribution when traffic is **heavy***. All the vehicles are forced to travel at much the same speed. Slow drivers tend to keep up with the traffic and fast drivers don't have room to overtake.

When the traffic is **light**, drivers can travel at whatever speed they choose, and the distribution is **wide**.

To see if this general rule applies to the road you studied, you may want to measure traffic when it is heavier (or lighter).

1.2 You could write a report on your investigations so that you can compare your results and observations with other groups. Include some statement about the traffic flow–whether it is light, moderate or heavy. You could also include answers to some of the following questions in your report.

☐ Were the vehicles few and far apart? Did the traffic move in a steady stream or in groups with large gaps between?

☐ Does your graph show that most vehicles travelled at about the same speed, as in the graph on page 27, or was there more variation?

☐ Did the fast and slow vehicles interfere with one another? Is the road safe for overtaking?

☐ Did parked cars interfere with the traffic flow?

☐ Did any vehicles exceed the speed limit? (See the conversion chart inside the back cover.) Do you think the speed limit is a sensible one, or should it be changed? Why?

☐ Was the traffic moving freely? If the speeds were mainly fast or slow, say why you think this was so.

Spot Speed

Speed measurement made at two positions close together is called spot speed.

There are other ways of measuring traffic speeds. One method is outlined on page 30.

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* The traffic is called heavy if the vehicles are following close to one another.

ACTIVITY 2: MEASURING PEDESTRIAN SPEEDS

One reason walking speeds are measured is so that 'walk' times can be set on traffic lights.

In this activity you can investigate whether there is much difference in the walking speeds of various groups of pedestrians.

It is a good idea to measure pedestrian speeds without letting the people know. In this way, you'll measure how fast people walk naturally–you can assume the pedestrians haven't stopped, speeded up or slowed down because they knew you were timing them.

Find a place where many people will be walking, preferably at a steady pace. This could be a foothpath in a shopping centre or along the way to school, or a school corridor.

You will probably find it easier to work with a partner.

You will need:

- 1 tape-measure
- 1 stop-watch.

Modify Activity 1 (Measuring Vehicular Speeds), pages 25–28, to apply to pedestrians.

Between 5 metres and 20 metres is usually a suitable distance for making pedestrian speed measurements.

Pick a place where you can see the markers at both ends of your measured distance, as in the diagram below.

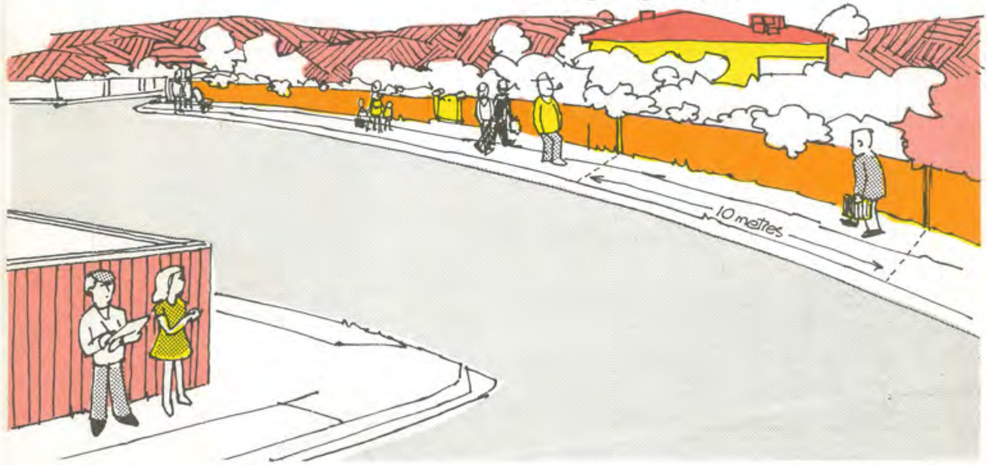
1.3 Decide how many pedestrian speeds you want to measure and prepare a table to record the results in your notebook before you start. You may want to investigate and compare the speeds of:

☐ Slow walkers with fast walkers.

☐ Older people with younger people.

☐ Students with teachers (going to class).

☐ Students walking to school with those going home.



ACTIVITY 3:
THE FLOATING CAR METHOD OF MEASURING AVERAGE SPEED

Knowledge of the average speed for a whole journey can be useful to motorists and traffic engineers.

Average journey speeds give traffic engineers useful information about traffic delays and reasons for them, e.g. traffic signals, shopping centres and car parking.

Sometimes motorists do not allow time for possible delays in trips. They are then tempted to drive too fast so that they won't be late.

The average speed for a whole journey can be found by the 'floating car' method. A car is driven at the speed of the general traffic flow–that is, it 'floats' in the traffic stream.

The floating car contains a driver and a passenger who records the total time taken for the journey, and the times during which the car is not moving. The next time you travel in a car in traffic, you could ask the driver to 'float' with the traffic, and you could record the details.

A stop-watch or stop-clock, and another watch or clock would be useful.

However, you could manage with a watch with a sweep second-hand if you had another passenger to record the results.

The following recordings and calculations were made by one group of students. Read through this example to see the method that they used.

DATE: 17 APRIL
DEPARTURE: 3.45 P.M.
ARRIVAL: 4.11 P.M.
TOTAL TIME: 26 MINUTES

JOURNEY FROM TOORAK TO CLAYTON
KILOMETRE READING AT START: 736.4
KILOMETRE READING AT FINISH: 750.6
DISTANCE TRAVELLED: 14.2 KILOMETRES

DELAYS	TIME
CAR TURNING	3 s
TURN ACROSS TRAFFIC	17 s
LIGHTS	11 s
LIGHTS	35 s
CAR TURNING	4 s
LEVEL CROSSING DELAY	62 s
LIGHTS	21 s
INTERSECTION DELAY	8 s
CAR TURNING	2 s
TURN ACROSS TRAFFIC	10 s
TOTAL DELAY	2 min 53 s (approx. 3 min)

$$\text{average speed for the journey} = \frac{\text{14.2 kilometres}}{\text{26 minutes}}$$

$$= \frac{14.2}{26} \times \frac{\text{60 kilometres}}{\text{1 hour}}$$

$$= \text{33 kilometres per hour}$$

33 kilometres per hour is the **average speed** for the journey

$$\text{total time in motion} = \text{26 minutes - 3 minutes}$$

$$= \text{23 minutes}$$

$$\text{average speed when car was moving} = \frac{\text{14.2 kilometres}}{\text{23 minutes}}$$

$$= \frac{14.2}{23} \times \frac{\text{60 kilometres}}{\text{1 hour}}$$

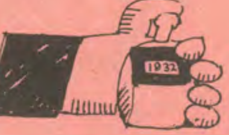
$$= \text{37 kilometres per hour}$$

37 kilometres per hour is the **average speed** for the time the car was moving.

✍ 1.4 Enter the results and calculations for your floating car journey. Suggest a likely average speed for the trip at 3 a.m. (almost no traffic), speed limit 60 kilometres per hour.

You can check your answer to ✍ 1.4 by turning to page 103.

OPTION 2



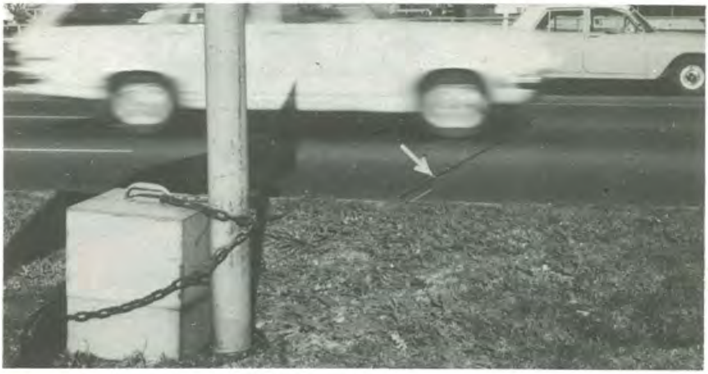
This option shows you ways of measuring traffic flow and investigating traffic flow patterns which affect you.
You can do some investigations which may help you understand a traffic system.

Traffic Counts and Flow

While the motorist is interested in how quickly and easily he can travel from one place to another, the traffic engineer is concerned with the pattern of movement of all the vehicles in an area.

People who plan traffic systems use traffic counts as the starting points for many of their investigations. A traffic planner needs to know about the likely uses of pedestrian crossings, school crossings, traffic signals and stop signs. He also needs to know about the likely traffic volume in a certain area at a certain time—for planning freeways, and designing roads and turning lanes, and so on. Information about short-time peaks, which can occur when people are going to work or school, for example, is necessary for timing traffic lights. If a road cannot carry all the traffic, a traffic jam develops.

You may understand more about the traffic planner's work if you do traffic counts yourself.

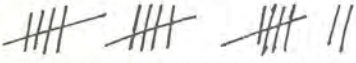


An automatic counter (like the one above) is sometimes used to provide data for road widening projects, installation of pedestrian crossings, and so on. Every time a vehicle crosses the rubber tube (arrowed), the counter records another number.

ACTIVITY 1: RECORDING TRAFFIC FLOW

It's easy to record traffic flow. This is usually done just by counting the number of vehicles passing your observation point in one direction in a given time interval–say, 1 minute or 1 hour.

A hand-operated counter may be a great help. Otherwise, if the traffic is not too heavy*, you could make a pencil stroke for each vehicle, like this:



This count represents 17 vehicles.

If the traffic is so heavy that you cannot watch and write at the same time, you will need to work with at least one partner. One person can count aloud as the vehicles pass; the other can record the counts on paper and watch the timing.

A hand-operated counter enables you to record without taking your eyes away from the traffic.

To avoid monotonous counting, you could 'sample' the traffic. For example, you could count for 3 minutes every 30 minutes, or 6 minutes every hour.

If you multiplied your totals by ten, this would give you an estimate of what the traffic count for 30 minutes or 1 hour might have been.

2.1 You could write a report on your investigations. If you want to compare your results with others, you will need to record such things as the date, time of day, place and time interval used.

Calculating Rates of Traffic Flow

Frequent studies are made of the number of vehicles using the main roads in Australia. Counts are made for certain lengths of time. The time intervals may vary from hours to a week or more. From such counts the rate of traffic flow can be calculated. The rate of traffic flow is the number of vehicles passing a fixed point in a certain time interval.

rate of traffic flow

$$= \frac{\text{number of vehicles passing}}{\text{time during which count was made}}$$

$$= \frac{n}{t}$$

There is a sample calculation on the next page.

*** Traffic is described as 'heavy' if vehicles are close to one another.**

Activity 1 continued next page

If 38 vehicles were counted over a 5-minute period passing a given point, you could work out the rate of traffic flow as shown at right.

$$\text{rate of traffic flow} = \frac{38 \text{ vehicles}}{5 \text{ minutes}}$$

$$= \frac{38 \text{ vehicles}}{5 \text{ minutes}} \times \frac{60 \text{ minutes}}{1 \text{ hour}}$$

$$= 456 \text{ vehicles per hour}$$

i.e. about 460 vehicles per hour (to the nearest 10)

This does not mean that 460 vehicles (or 456) would be counted in a full hour. It does, however, provide a number which is useful for comparing the rate of traffic flow at different times during the day.

You may want to calculate the rate of traffic flow during your observation time, using the results of your counts.

ACTIVITY 2: TRAFFIC FLOW PATTERNS

The traffic flow on a particular road usually follows a pattern–it is usually heavier at certain times of the day and on certain days of the week. You could plan an investigation of the traffic flow pattern on a road accessible to you. You will probably need to work as one of a group.

To find a flow pattern, you need to count samples of the traffic during most of one day from, say, 6 a.m. to 10 p.m.

☐ Decide which section of road you will study.
☐ Decide at what times you can make counts.
☐ Work out a roster system–that is, who will count the traffic at which times.
☐ Plan a sampling procedure on the basis of Activity 1. For example, you may decide to make counts every hour or half an hour at peak periods, but every 2 hours at other times. Someone in your group may be able to record counts early in the morning or late at night.

✎ 2.2 Record all counts, calculate the hourly flow rates, and graph this information. The graph will help you to see the flow pattern easily.

7 You can record your results in your notebook in a table like the one below. Then try to answer the question: Which surface reduced the friction most?

SURFACE	DISTANCE TRAVELLED
SMOOTH	DO NOT WRITE IN THIS TABLE
WITH TALC	
WITH POLYSTYRENE BEADS	

8 'Super beads', used by hovercraft, are air molecules which are better than any of the friction-reducing substances you have tried.

☐ How far do you think your block could travel on 'super beads', if you could use them?

☐ How does air reduce friction for a hovercraft?

9 You should have enough information now to write an account of your investigation.

10 A hovercraft needs a constant force to keep it moving at a steady speed. Try to explain this.

SUMMING UP

☐ To start an object moving a force (push) is needed. An opposing force such as friction slows down a moving object.

☐ Without friction or other forces acting on it a moving object would keep going at the same speed for ever. Its speed would not change.

FINDING AVERAGE SPEEDS IN EVERYDAY LIFE

You should now have some idea how to measure average speed.

Discuss with a teacher which speed you want to measure and whether it is safe to do so. Here are some suggestions.

Cars

If you are near a busy road and can get permission, you could find the average speed of passing cars. If you think you'd like to do that, you could check procedures in Option 1 (Measuring Speeds), page 24.

Pedestrians

If you want to time some fellow students walking along a corridor, you can find out about that in Option 1, too–see Activity 2 (Measuring Pedestrian Speeds), page 29. You may be able to work out a speed at which students should usually try to walk in the corridors at your school.

Athletes

If there is a sports meeting on, or some students are practising running, you could find average speeds of the athletes. You could comment on changes in the speeds during take-off, the main run and the end of a sprint.

Conversion Chart

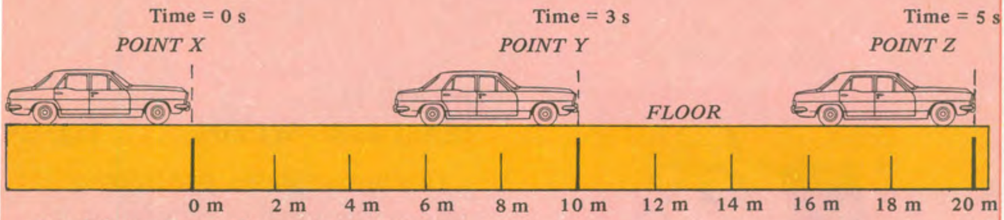
There is a conversion chart inside the back cover of this book to help you convert readings from one set of speed units to another. You will probably find this useful when making notes about your investigations.

TEST YOURSELF—AVERAGE SPEEDS AND FORCES

Answer the following questions in your notebook.

Questions 16–19

A toy car began to move from point X on the floor of a corridor. Three seconds later the front of the car was at point Y. Five seconds after starting the front of the car was at point Z. The distances travelled are shown on the diagram below.



Read distances to the nearest metre.

16 How long did it take the toy car to travel from point Y to point Z?

17 How far did the car travel in moving from point Y to point Z?

18 What was the average speed of the car in travelling from point Y to point Z?

19 What was the average speed of the car in travelling from point X to point Z?

---

20 Which one of the following statements about the motion of an object and the force acting on the object is NOT correct?

A If there is no force acting on a moving object, it will gradually slow down.

B For a stationary object to start moving, it must be acted on by a force.

C A moving object must be acted on by a force in order to stop it moving.

D A force is necessary to make a moving object move faster.

21 If a car is travelling at a steady speed along a straight road, the force of the engine pushing the car forward is

A greater than all the resistance forces on the car.

B equal to all the resistance forces on the car.

C less than all the resistance forces on the car.

D greater than, equal to, or less than all the resistance forces on the car, depending on the speed of the car.

Now turn to Check Your Answers on page 102.

ABOUT THE OPTIONS

Here are summaries to help you decide which options to choose.

OPTION 1:
MEASURING SPEEDS . . . Page 24

This option shows you how to measure the speed of vehicles on a road and of pedestrians on a footpath or in a school.

OPTION 2:
TRAFFIC COUNTS AND FLOW . . . . Page 32

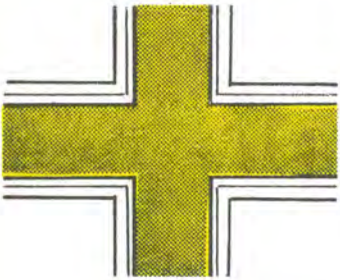
You can make sample counts of moving vehicles, and investigate traffic flow patterns which affect you.

OPTION 3:
COLLISIONS . . . . Page 42

Forces not only stop moving objects, but start them moving, too. These forces have effects on cars and drivers. (What is whip-lash injury?) There are some calculations for those who like mathematics.

OPTION 4:
STOP! . . . . Page 56

You measure your reaction time, and find out about the least stopping distance at a given speed. You may be able to design a safer car.

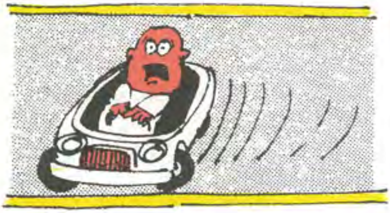


OPTION 5:
INTERSECTIONS . . . . Page 71

Intersections can cause traffic delays and accidents. This option shows you how to investigate ways in which delays may be reduced and safety increased.

OPTION 6:
TRAFFIC ENGINEERS . . . Page 80
You need to do Options 2 and 5 before doing Option 6.

This is an option about traffic engineers and the way some of them tackled a particular problem. It may help you to work out ways of investigating a traffic problem in your own area.



OPTION 7:
SKIDDING . . . . Page 86

Can a car stop quickly after a shower of rain? What happens if the rear wheels of a car lock on braking? You can use a cart to find answers to these and other questions.

OPTION

1

This option shows you ways of measuring vehicle and pedestrian speeds, and how to represent speeds on a distribution graph.

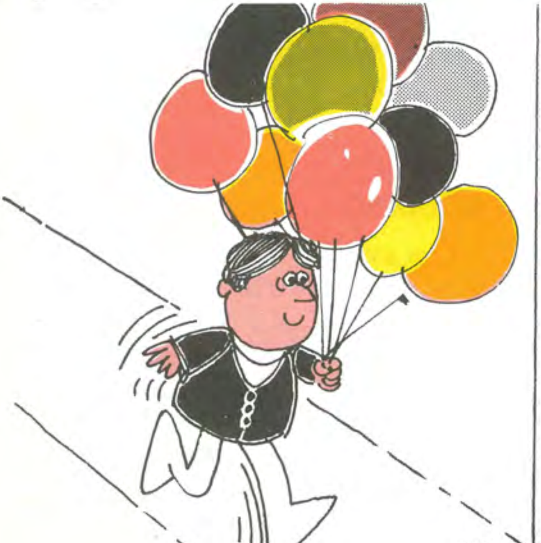
Measuring Speeds

In a traffic system, not all the people or all the vehicles move at the same speed.

On the road, there are fast drivers and slow drivers. On a footpath, some people walk slowly, while others are in a great hurry.

A knowledge of vehicle and pedestrian speeds is useful for the engineer planning roads. For example, pedestrian speeds can be used to decide how much time is needed for a group of pedestrians to cross a road, and the traffic lights can be set accordingly. If the speed at which trucks climb a hill is known, suitable passing lanes for cars can be built.

You may want to study an actual traffic situation. You could study road traffic, or pedestrian traffic on a footpath or perhaps in your school corridor. Activities 1 and 2 describe some methods that you could follow, although you may want to modify them, or think up others.



ACTIVITY 1: MEASURING VEHICULAR SPEEDS

Sometimes vehicles are timed over a measured distance. Here and on the next page are two ways you can do this. You will need to work with at least one partner, whatever way you do it.

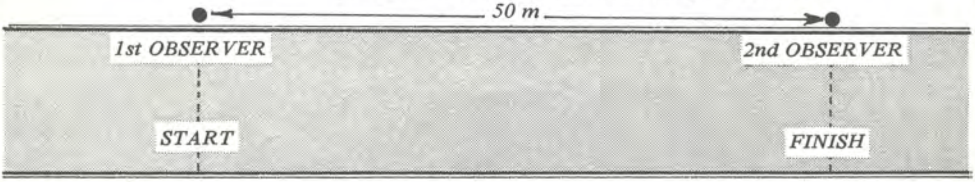
METHOD 1: Choose two power poles (or other distinct objects) a suitable distance apart to mark the start and finish. When a vehicle passes the start, the partner there drops his arm. This is the signal to the partner at the finish to start timing with the stop-watch.

You will need (for either method):
- 1 tape-measure–to measure up to 50 m
- 1 stop-watch.

Timing

For timing, choose a straight section of the road where you can see the cars coming well before they reach you. Avoid places near traffic lights, intersections or shopping centres where there are likely to be traffic hold-ups.

Any distance can be used, but if the distance is too short, you may not be able to time cars accurately. If the distance is too long, it may be hard to see when a car crosses the start and finish of the measured distance. The diagram below shows a convenient distance, 50 metres.



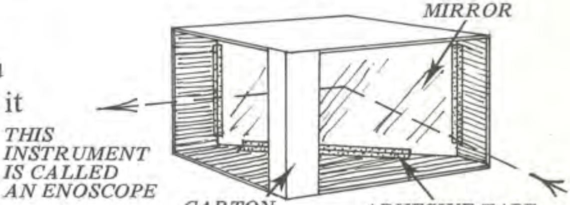
Activity 1 continued next page

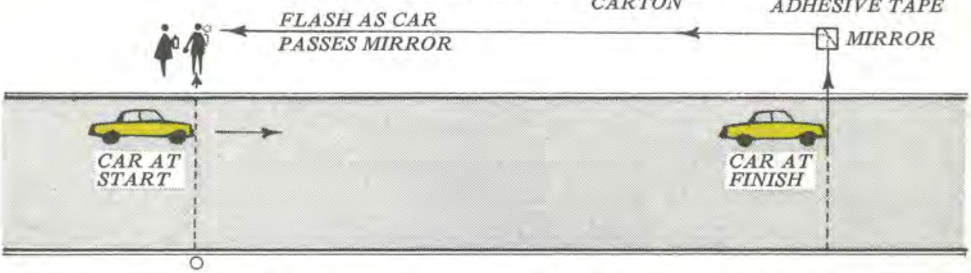
METHOD 2:

Use a mirror mounted in a box so that it can be set at 45° to the road. As the vehicle passes the start one partner can begin timing with the stop-watch. He then watches for the flash in the mirror as the vehicle passes the finish line. The other partner does the recording. If you want to use this method, practise it first.

If you use method 2, the mirror method, you will also need:

- 1 large mirror, about 20 cm × 30 cm
- 1 cardboard carton, about 30 cm × 20 cm × 20 cm
- adhesive tape.





You may be able to time every vehicle, but if there are too many you could 'sample' them. For example, you could time every second, or perhaps every fifth, vehicle.

This method will enable you to get results which represent fairly the traffic passing, i.e. a sample which isn't **biased**.

It may be best to time the vehicles in only one direction, if there is a lot of traffic. If there isn't much traffic, you could time the vehicles going both ways. If you do this, record your results for each way separately.

Thirty would be about the smallest sample from which you could get useful results. The more vehicles you time, the better your sample will be. On the other hand, it may be monotonous to time a large number of vehicles, and to calculate all their speeds.

You may want to share this task among several people. Working in groups of two or three should be satisfactory.

You can use the speed calculator on the back cover to convert your results to speeds.

RECORDING AND DISPLAYING VEHICLE SPEEDS

1.1 Design a sheet for recording all the information you collect. The one shown opposite was used by one group of students.

One way traffic engineers display information about vehicle speed is on a speed distribution graph. To plot the speed distribution of traffic, you need to time a fairly large number of vehicles. The information and the graph which shows it are on the opposite page.

TRAFFIC SPEED COUNT

DATE: 17 APRIL
DAY: TUESDAY
TIME: 1 P.M.

LOCATION: TOORAK ROAD, MALVERN
DIRECTION OF TRAVEL: EAST
MEASURED DISTANCE: (d): 50 METRES

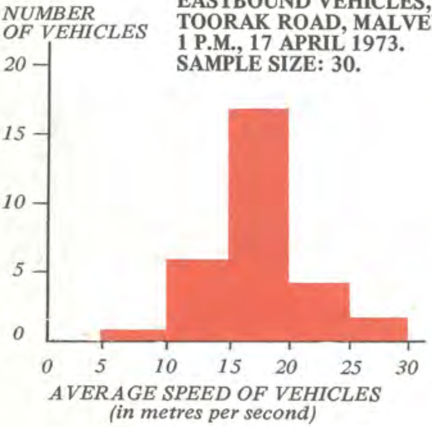
OBSERVERS:
R.SHEPHERD
I.MARTIN

TIME in seconds	**SPEED** in metres* per second	**TIME** in seconds	**SPEED** in metres* per second	**TIME** in seconds	**SPEED** in metres* per second
3.0	17	4.6	11	1.9	28
3.6	14	3.0	17	2.7	19
1.9	28	2.8	18	3.1	17
3.0	17	5.2	9	3.1	17
2.7	19	2.4	21	3.5	15
2.9	18	2.0	25	3.4	15
2.4	21	3.0	17	2.6	19
2.5	20	3.0	17	2.4	21
3.7	14	3.0	17	3.0	17
3.2	16	4.4	12	2.6	19

* To the nearest whole number.

SPEED BANDS	**NUMBER OF VEHICLES WITH SPEEDS IN THAT BAND**
0 m/s to 5 m/s	0
6 m/s to 10 m/s	1
11 m/s to 15 m/s	6
16 m/s to 20 m/s	17
21 m/s to 25 m/s	4
26 m/s to 30 m/s	2
Total:	30

SPEED DISTRIBUTION, EASTBOUND VEHICLES, TOORAK ROAD, MALVERN, 1 P.M., 17 APRIL 1973. SAMPLE SIZE: 30.



The fastest speed the Malvern group recorded was 28 metres per second, and the slowest speed was 9 metres per second. All the speeds can be sorted out into groups, or 'speed bands' as shown at left.

Each band in a speed band table should be the same 'width'. Each 'width' in this table is 5 metres per second. If the bands are the same width, the number of vehicles and their speeds can be compared easily on a distribution graph like the one on this page.

Some points to watch when constructing your distribution graph are:

☐ label the graph clearly, so that it explains itself, and
☐ make the bands stand out clearly.

Activity 1 continued next page

Generally, there is a **narrow** distribution when traffic is **heavy***. All the vehicles are forced to travel at much the same speed. Slow drivers tend to keep up with the traffic and fast drivers don't have room to overtake.

When the traffic is **light**, drivers can travel at whatever speed they choose, and the distribution is **wide**.

To see if this general rule applies to the road you studied, you may want to measure traffic when it is heavier (or lighter).

1.2 You could write a report on your investigations so that you can compare your results and observations with other groups. Include some statement about the traffic flow—whether it is light, moderate or heavy. You could also include answers to some of the following questions in your report.

☐ Were the vehicles few and far apart? Did the traffic move in a steady stream or in groups with large gaps between?

☐ Does your graph show that most vehicles travelled at about the same speed, as in the graph on page 27, or was there more variation?

☐ Did the fast and slow vehicles interfere with one another? Is the road safe for overtaking?

☐ Did parked cars interfere with the traffic flow?

☐ Did any vehicles exceed the speed limit? (See the conversion chart inside the back cover.) Do you think the speed limit is a sensible one, or should it be changed? Why?

☐ Was the traffic moving freely? If the speeds were mainly fast or slow, say why you think this was so.

Spot Speed

Speed measurement made at two positions close together is called spot speed.

There are other ways of measuring traffic speeds. One method is outlined on page 30.

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* The traffic is called heavy if the vehicles are following close to one another.

ACTIVITY 2: MEASURING PEDESTRIAN SPEEDS

One reason walking speeds are measured is so that 'walk' times can be set on traffic lights.

In this activity you can investigate whether there is much difference in the walking speeds of various groups of pedestrians.

It is a good idea to measure pedestrian speeds without letting the people know. In this way, you'll measure how fast people walk naturally–you can assume the pedestrians haven't stopped, speeded up or slowed down because they knew you were timing them.

Find a place where many people will be walking, preferably at a steady pace. This could be a foothpath in a shopping centre or along the way to school, or a school corridor.

You will probably find it easier to work with a partner.

You will need:

- 1 tape-measure
- 1 stop-watch.

Modify Activity 1 (Measuring Vehicular Speeds), pages 25–28, to apply to pedestrians.

Between 5 metres and 20 metres is usually a suitable distance for making pedestrian speed measurements.

Pick a place where you can see the markers at both ends of your measured distance, as in the diagram below.

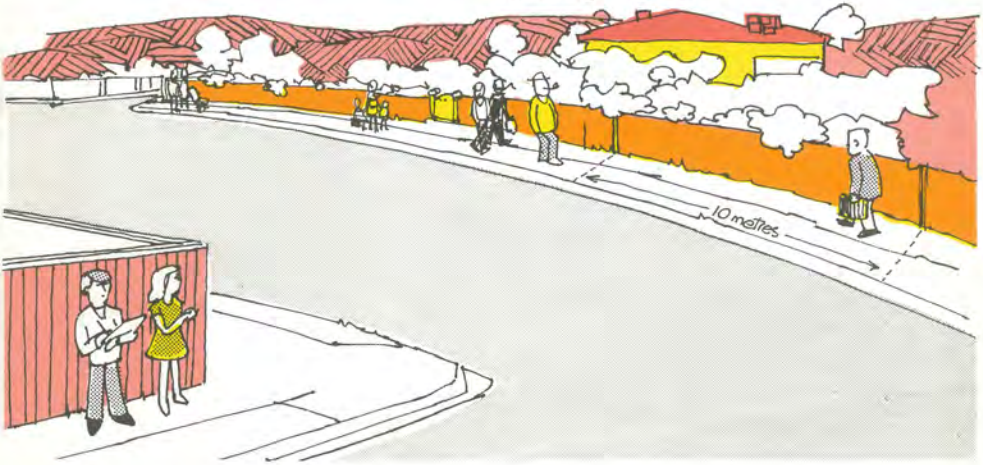
1.3 Decide how many pedestrian speeds you want to measure and prepare a table to record the results in your notebook before you start. You may want to investigate and compare the speeds of:

☐ Slow walkers with fast walkers.

☐ Older people with younger people.

☐ Students with teachers (going to class).

☐ Students walking to school with those going home.



ACTIVITY 3:
THE FLOATING CAR METHOD OF MEASURING AVERAGE SPEED

Knowledge of the average speed for a whole journey can be useful to motorists and traffic engineers.

Average journey speeds give traffic engineers useful information about traffic delays and reasons for them, e.g. traffic signals, shopping centres and car parking.

Sometimes motorists do not allow time for possible delays in trips. They are then tempted to drive too fast so that they won't be late.

The average speed for a whole journey can be found by the 'floating car' method. A car is driven at the speed of the general traffic flow–that is, it 'floats' in the traffic stream.

The floating car contains a driver and a passenger who records the total time taken for the journey, and the times during which the car is not moving. The next time you travel in a car in traffic, you could ask the driver to 'float' with the traffic, and you could record the details.

A stop-watch or stop-clock, and another watch or clock would be useful.

However, you could manage with a watch with a sweep second-hand if you had another passenger to record the results.

The following recordings and calculations were made by one group of students. Read through this example to see the method that they used.

DATE: 17 APRIL
DEPARTURE: 3.45 P.M.
ARRIVAL: 4.11 P.M.
TOTAL TIME: 26 MINUTES

JOURNEY FROM TOORAK TO CLAYTON
KILOMETRE READING AT START: 736.4
KILOMETRE READING AT FINISH: 750.6
DISTANCE TRAVELLED: 14.2 KILOMETRES

DELAYS	TIME
CAR TURNING	3 s
TURN ACROSS TRAFFIC	17 s
LIGHTS	11 s
LIGHTS	35 s
CAR TURNING	4 s
LEVEL CROSSING DELAY	62 s
LIGHTS	21 s
INTERSECTION DELAY	8 s
CAR TURNING	2 s
TURN ACROSS TRAFFIC	10 s
TOTAL DELAY	2 min 53 s (approx. 3 min)

average speed for the journey $= \dfrac{14.2 \text{ kilometres}}{26 \text{ minutes}}$

$$= \frac{14.2}{26} \times \frac{60 \text{ kilometres}}{1 \text{ hour}}$$

$$= 33 \text{ kilometres per hour}$$

33 kilometres per hour is the **average speed** for the journey

total time in motion $= 26 \text{ minutes} - 3 \text{ minutes}$

$$= 23 \text{ minutes}$$

average speed when car was moving $= \dfrac{14.2 \text{ kilometres}}{23 \text{ minutes}}$

$$= \frac{14.2}{23} \times \frac{60 \text{ kilometres}}{1 \text{ hour}}$$

$$= 37 \text{ kilometres per hour}$$

37 kilometres per hour is the **average speed** for the time the car was moving.

✍ 1.4 Enter the results and calculations for your floating car journey. Suggest a likely average speed for the trip at 3 a.m. (almost no traffic), speed limit 60 kilometres per hour.

You can check your answer to ✍ 1.4 by turning to page 103.

OPTION

2

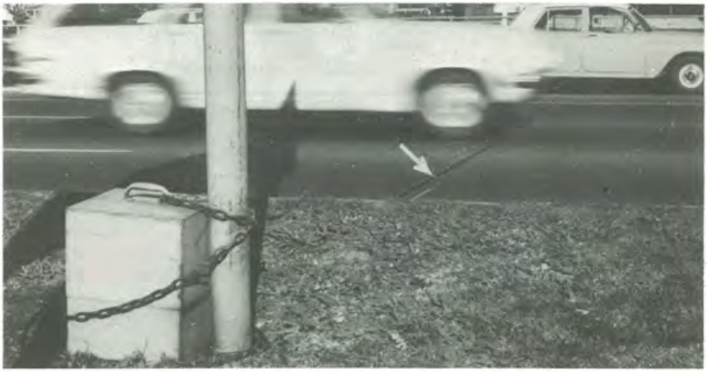
**This option shows you ways of measuring traffic flow and investigating traffic flow patterns which affect you.
You can do some investigations which may help you understand a traffic system.**

Traffic Counts and Flow

While the motorist is interested in how quickly and easily he can travel from one place to another, the traffic engineer is concerned with the pattern of movement of all the vehicles in an area.

People who plan traffic systems use traffic counts as the starting points for many of their investigations. A traffic planner needs to know about the likely uses of pedestrian crossings, school crossings, traffic signals and stop signs. He also needs to know about the likely traffic volume in a certain area at a certain time—for planning freeways, and designing roads and turning lanes, and so on. Information about short-time peaks, which can occur when people are going to work or school, for example, is necessary for timing traffic lights. If a road cannot carry all the traffic, a traffic jam develops.

You may understand more about the traffic planner's work if you do traffic counts yourself.

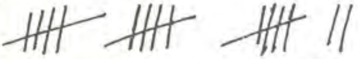


An automatic counter (like the one above) is sometimes used to provide data for road widening projects, installation of pedestrian crossings, and so on. Every time a vehicle crosses the rubber tube (arrowed), the counter records another number.

ACTIVITY 1: RECORDING TRAFFIC FLOW

It's easy to record traffic flow. This is usually done just by counting the number of vehicles passing your observation point in one direction in a given time interval–say, 1 minute or 1 hour.

A hand-operated counter may be a great help. Otherwise, if the traffic is not too heavy*, you could make a pencil stroke for each vehicle, like this:



This count represents 17 vehicles.

If the traffic is so heavy that you cannot watch and write at the same time, you will need to work with at least one partner. One person can count aloud as the vehicles pass; the other can record the counts on paper and watch the timing.

A hand-operated counter enables you to record without taking your eyes away from the traffic.

To avoid monotonous counting, you could 'sample' the traffic. For example, you could count for 3 minutes every 30 minutes, or 6 minutes every hour.

If you multiplied your totals by ten, this would give you an estimate of what the traffic count for 30 minutes or 1 hour might have been.

2.1 You could write a report on your investigations. If you want to compare your results with others, you will need to record such things as the date, time of day, place and time interval used.

Calculating Rates of Traffic Flow

Frequent studies are made of the number of vehicles using the main roads in Australia. Counts are made for certain lengths of time. The time intervals may vary from hours to a week or more. From such counts the rate of traffic flow can be calculated. The rate of traffic flow is the number of vehicles passing a fixed point in a certain time interval.

rate of traffic flow

$$= \frac{\text{number of vehicles passing}}{\text{time during which count was made}}$$

$$= \frac{n}{t}$$

There is a sample calculation on the next page.

*** Traffic is described as 'heavy' if vehicles are close to one another.**

Activity 1 continued next page

If 38 vehicles were counted over a 5-minute period passing a given point, you could work out the rate of traffic flow as shown at right.

$$\text{rate of traffic flow} = \frac{38 \text{ vehicles}}{5 \text{ minutes}}$$

$$= \frac{38 \text{ vehicles}}{5 \text{ minutes}} \times \frac{60 \text{ minutes}}{1 \text{ hour}}$$

$$= 456 \text{ vehicles per hour}$$

i.e. about 460 vehicles per hour (to the nearest 10)

This does not mean that 460 vehicles (or 456) would be counted in a full hour. It does, however, provide a number which is useful for comparing the rate of traffic flow at different times during the day.

You may want to calculate the rate of traffic flow during your observation time, using the results of your counts.

ACTIVITY 2: TRAFFIC FLOW PATTERNS

The traffic flow on a particular road usually follows a pattern—it is usually heavier at certain times of the day and on certain days of the week. You could plan an investigation of the traffic flow pattern on a road accessible to you. You will probably need to work as one of a group.

To find a flow pattern, you need to count samples of the traffic during most of one day from, say, 6 a.m. to 10 p.m.

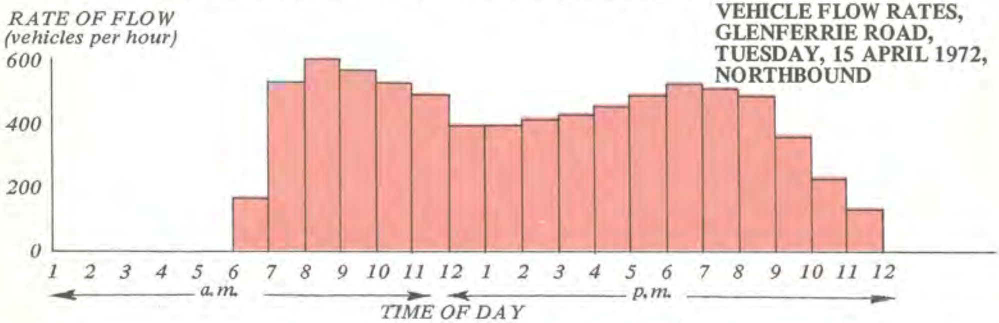
☐ Decide which section of road you will study.
☐ Decide at what times you can make counts.
☐ Work out a roster system—that is, who will count the traffic at which times.
☐ Plan a sampling procedure on the basis of Activity 1. For example, you may decide to make counts every hour or half an hour at peak periods, but every 2 hours at other times. Someone in your group may be able to record counts early in the morning or late at night.

2.2 Record all counts, calculate the hourly flow rates, and graph this information. The graph will help you to see the flow pattern easily.

Here is one way you can record counts.

LOCATION:		**DATE:**		**DAY:** ....
OBSERVERS:		....		
TIME OF DAY	**NUMBER OF VEHICLES COUNTED** n	**COUNT TIME IN MINUTES** t	**RATE OF FLOW VEHICLES PER HOUR** $\frac{n}{t} \times \frac{60}{1}$	**COMMENTS**
.... a.m. .... p.m.				

The graph below shows one way to plot the rate of flow throughout one day.



VEHICLE FLOW RATES, GLENFERRIE ROAD, TUESDAY, 15 APRIL 1972, NORTHBOUND

Whichever type of graph you use, make sure that:

☐ the graph is fully labelled, so that **it is self-explanatory**, and

☐ the pattern that you want to show stands out clearly.

2.3 Your graph should help you see changes in the traffic flow rate. You could write a report on your observations. Here are some of the features you may wish to discuss:

☐ the time of the highest flow rate;

☐ the probable time of the lowest flow rate;

☐ whether there is any temporary falling off in the flow rate during the day; and

☐ why the kind of pattern shown in your graph occurs.

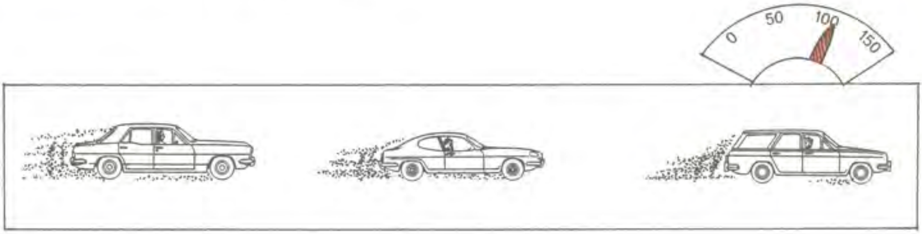
If groups in other schools have carried out a similar investigation, you may want to compare the two sets of results.

CARRYING CAPACITY

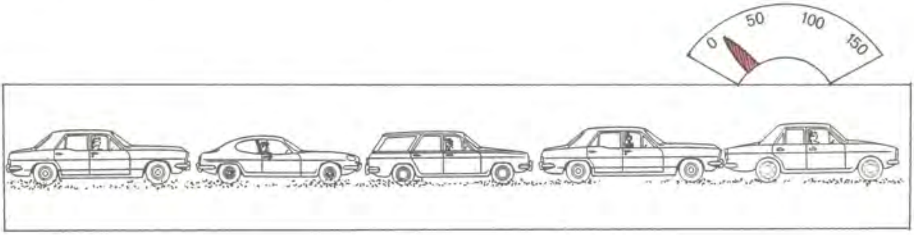
The carrying capacity of a road is the greatest rate of flow that can occur on that road.

If the traffic is light, the vehicles are usually far apart and can travel fast. However, the total number of vehicles passing per hour is usually small.

If the traffic is moderate, the vehicles can travel almost as fast and the rate of flow can be much higher.



If the traffic is heavy, the vehicles are usually close together. Then vehicles tend to slow down, and the rate of flow may be less.



ACTIVITY 3: A COMBINED SURVEY

If you have done Option 1 (Measuring Speeds), you could do a combined traffic survey—to measure traffic flow and traffic speeds at the same time.

2.4 Here are some suggestions and questions to help you plan your survey.

☐ At what times of the day between 8 a.m. and 6 p.m. do the cars move fastest?

☐ At what times of the day is the rate of flow highest?

☐ What are the speeds of cars when the traffic flow is greatest?

☐ You have probably heard that for every 15 kilometres per hour there should be one car length distance for safe stopping. Estimate the distance between cars in terms of car lengths—and work out how safety-conscious the drivers were who passed you. (You can find out more about safety on the roads in Option 4.)

A high rate of traffic flow on a major road can be maintained if delays are reduced by overpasses and planned access roads such as those shown in the photo above.
(Photo by courtesy of Country Roads Board of Victoria.)

ACTIVITY 4: A TRAFFIC FLOW MAP

You will need:

- 1 map of the 'catchment area' of your school
- coloured marking pens
- 1 sheet of transparent overlay–if the map is to be used again.

You will also need the co-operation of 30 or more students!

When you arrive at school many others who have travelled from widely scattered areas are arriving, too. You all form part of a traffic flow. To find out more about this type of traffic flow, you could plot the routes of some students.

The map and the overlay should be pinned to a notice-board (or large sheet of thumb-tack board). The map will need to cover every area in which the 30 or more students live. Each student marks (on the overlay) where he lives and his route to school with a marking pen. You may be able to get other students from your school to help to build up a clearer pattern.

When the group has finished you could examine the routes for features such as the ones listed below.

□ Which are the roads which carry large numbers of students to school–the 'main' roads?

□ Which are the roads along which several students travel toward 'main' roads to the school?

□ Which are the problem areas–where the traffic flow to school intersects with flow to other places? These could be where some students have to cross a busy road, or an uncontrolled intersection. There could be other problem areas, too.

The students shown in the photo are marking their routes to school on an overlay which covers the map.

2.5 Here are some other points you could comment on:

☐ Does the school entrance become a traffic hazard?

☐ Do any places of business nearby have a similar traffic flow? Is a problem created by these flows intersecting with the flow of students to school?

☐ Would a different starting time for the school (or the businesses) reduce these problems? What are your suggestions?

2.6 What would be the advantages and disadvantages of flexible* working hours in a large town where there is a traffic congestion problem?

* For some occupations, working hours have already been made flexible. A person might be required to work a total of 40 hours weekly, but he can start early and finish early if he chooses, providing he is at work between 10.30 a.m. and 3.30 p.m. In what type of work could this be possible? Can you think of any problems this system could cause?

FURTHER ACTIVITIES You could obtain a map of a large area and survey the traffic flow to places such as:

☐ a railway station,

☐ a shopping area, or

☐ a library or cinema.

You could obtain a plan of your school and investigate the pattern of movement of groups when they change rooms. You may be able to suggest routes which could reduce congestion and delays.

Do ants have any regular pattern of movement within and without their nests? Is there any particular pattern common to one type of ant?

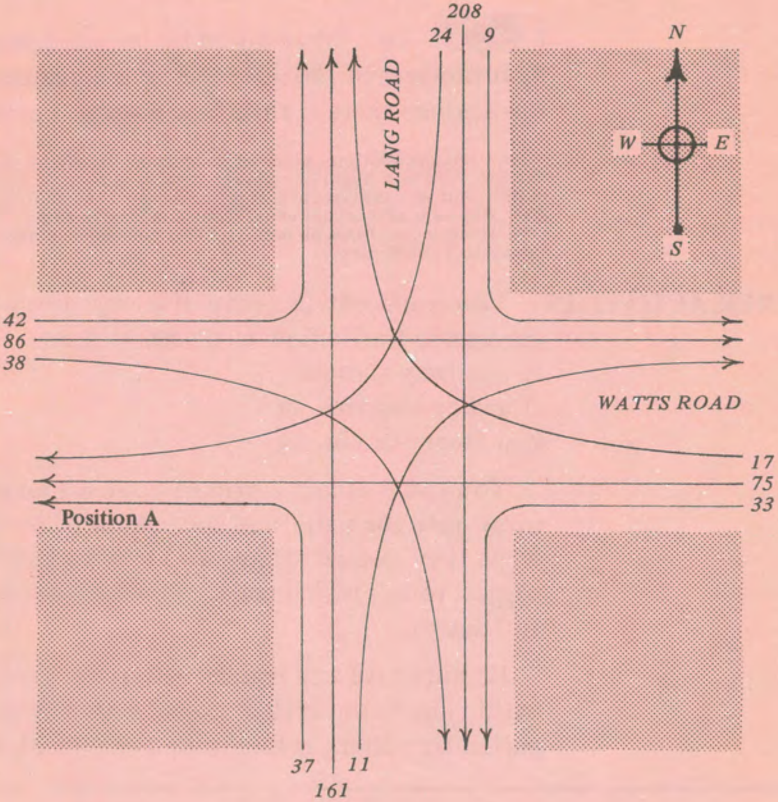
SUMMING UP

The traffic system is made up of many flows such as you have investigated. Changes to one part of the system may also affect the other parts. (Look at the effect of a set of pedestrian lights along a road which carries a large number of vehicles.) Traffic planners have to try to take into account the requirements of everyone when planning roads.

TEST YOURSELF–TRAFFIC COUNTS AND FLOW

Answer the following questions in your notebook.

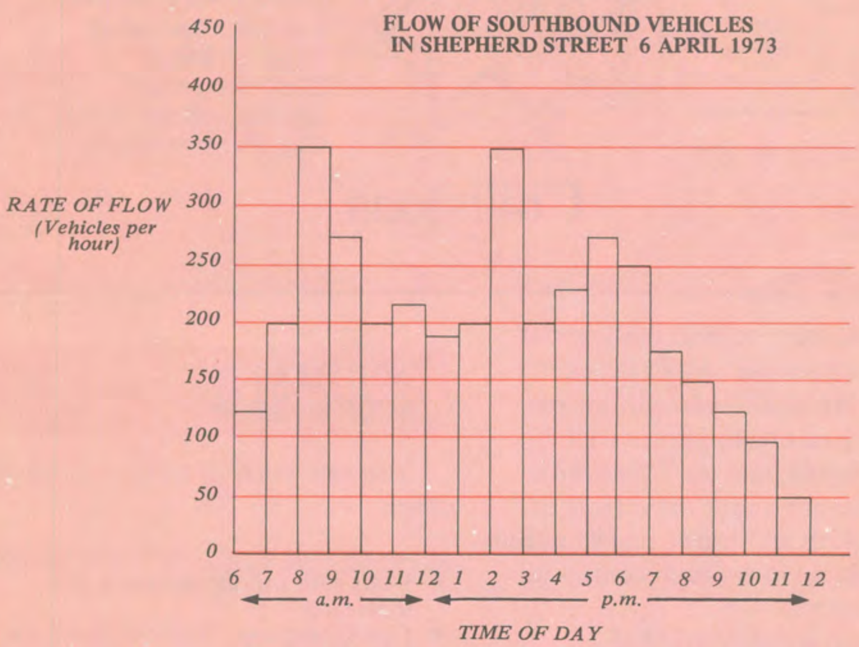
1 The diagram below represents the intersection of Watts and Lang Roads. The figures indicate the number of vehicles which travelled through and/or turned at the intersection from 8 a.m. to 10 a.m. on 8 December 1973.
For example, 161 vehicles travelling north along Lang Road passed through the intersection without turning and 17 vehicles travelling west along Watts Road turned north into Lang Road.



What was the rate of traffic flow travelling west along Watts Road past position A? Give your answer in vehicles per hour.

Questions 2–4 refer to the bar graph below.

A group of students took six-minute sample counts every hour of the number of vehicles which travelled in a southerly direction along Shepherd Street. From their sample results they constructed the bar graph below.



2 According to the bar graph, how many southbound vehicles passed the observation point between 10 a.m. and 2 p.m.?

3 Does the answer to question 2 give the exact number of southbound vehicles which actually passed the observation point? Justify your answer.

4 What explanation can you offer to account for the rise in the rate of flow between 2 p.m. and 3 p.m.?

---

5 In an Australian city, vehicles are prohibited from turning off a section of the main street between 12.30 p.m. and 2 p.m. on weekdays. Before this regulation was introduced, an investigation showed that on weekdays the number of vehicles on the main street at any time between 10 a.m. and 4 p.m. remained fairly constant.
What reason can you offer to explain why this regulation was introduced?

Now turn to Check Your Answers on page 103.

OPTION 3

The forces which start and stop cars affect drivers and passengers, too. In this option you find out why we wear seat belts and what whiplash injury is. There are some calculations for those who like mathematics.

Collisions

You can read or hear daily about collisions between cars or between cars and trees–and you can see the horrifying results in photos such as the one below, and on TV screens.

To find out about the effects of sudden stops and starts, real situations are simulated in research centres all over the world.

You can simulate real life happenings, too.

You can use a cart instead of a car and a small disc and plasticine to represent the driver.

(Photo by courtesy of The Age, *Melbourne.)*

ACTIVITY 1: SUDDEN STOP

You can work on a table, or on the floor.

If you are working on a table, you will need:

- 1 cart with a spring bumper and a starter pin
- 1 cardboard tray, about 20 cm × 5 cm, with the side edges bent up
- 1 table, about 1.5 m long
- 1 ruler
- 1 small amount of plasticine
- 1 20c coin (or metal washer)
- 1 barrier
- 2 G clamps
- 1 piece of aluminium foil, about 30 cm × 15 cm–optional.

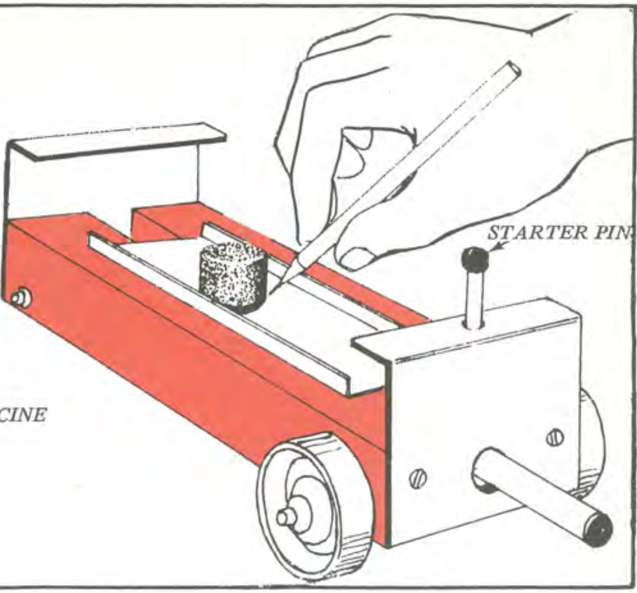
If you are working on the floor, you will need everything listed above, but you will need to work out a way of setting up the barrier. You may have to use something other than the barrier held with the G clamps.

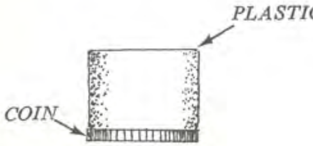
If you haven't got a table, and you can't set up a barrier on the floor, you could push the cart against a wall.

Place the tray (the driver's seat) on the cart.

Knead the plasticine into a disc and stick it to the coin.

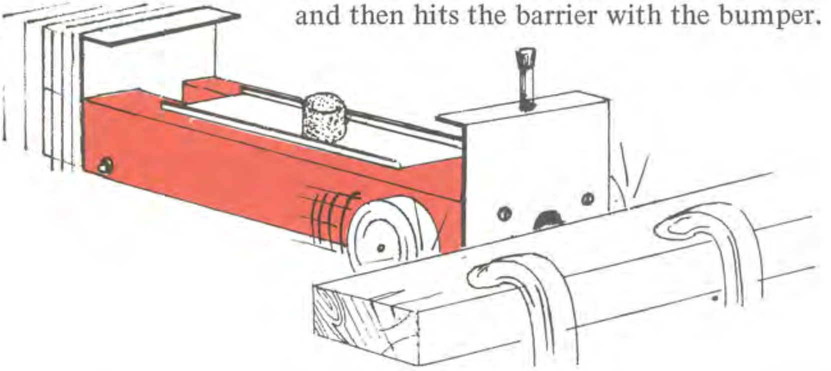
Place the disc into the middle of the tray and mark its outline with a pencil.





Clamp the barrier to one end of the table.

Leave the bumper of the cart sticking out. Push the cart so that it runs along the table and then hits the barrier with the bumper.



3.1 Give the cart a number of pushes, gently at first and then harder. Measure and record the distance the disc-driver moved in each case.

3.2 Before the collision the cart and disc were moving forward. At the collision, the cart stopped. What happened to the disc? Try to account for its behaviour.

Activity 1 continued next page

In Activity 2 (Cart Speeds), page 12, you saw that a force (push) was needed to start the cart moving and another force (friction) slowed it down to a stop. All moving objects require a force to stop them. Here in the collision, the barrier supplied the force which stopped the cart. The disc, too, needs a force to stop it.

> The resistance of a car, or a driver (or anything else), to changes in motion, such as stopping, is called **inertia.**

✍ 3.3 Discuss whether the driver is really 'thrown' through the windscreen when a car stops suddenly.

✍ 3.4 Discuss with others the advantages and disadvantages of various designs of seat belts.

✍ 3.5 Car bumper bars were designed originally to protect the car and its occupants. You could examine some parked cars and try to decide how useful bumpers might be for this purpose. Include some pre-1940 model cars in your survey, if you can.

A FURTHER ACTIVITY

Loosely roll some aluminium foil (about 30 centimetres by 15 centimetres) to form a roughly crumpled cylinder (about 15 centimetres by 5 centimetres).

This foil cylinder can be used to represent the front of a car designed to 'give' and absorb some of the shock of a collision.

Repeat Activity 1 using the crushable foil instead of the spring bumper between the moving cart and the barrier. Compare the motion of the disc with and without the foil.

✍ 3.6 You could discuss your findings with other students and write a brief report.

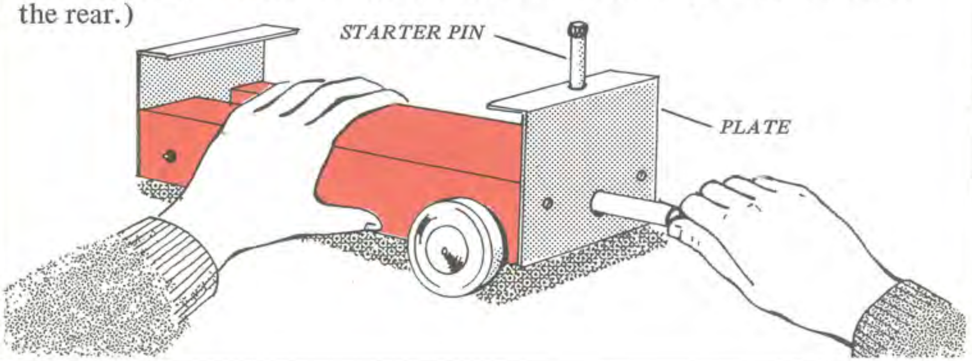
Properly fitted seat belts reduce the danger of injury by providing a force to stop the occupants of a car.

ACTIVITY 2: SUDDEN START

You have observed what happens to disc-drivers when carts stop suddenly. However, collisions frequently cause vehicles to move forward suddenly. These collisions also result in damage to people and vehicles.

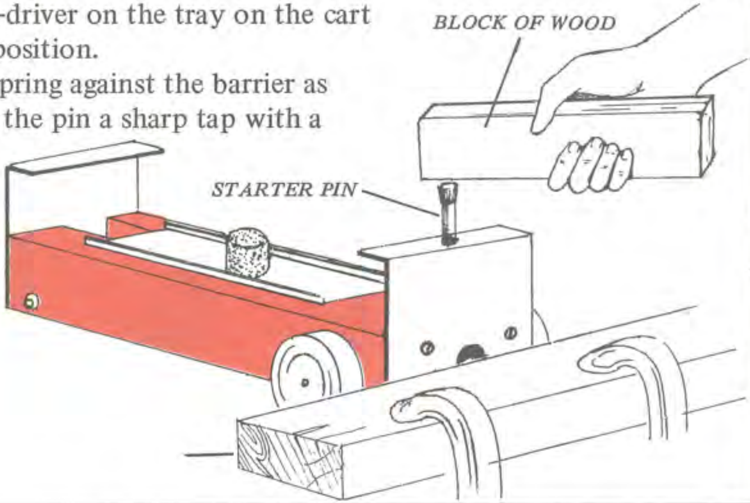
To study the effects of sudden starts, you will need the equipment from Activity 1.

Push the spring bumper into the tube of the cart and under the plate as shown here. (What was the front of the cart in Activity 1 now becomes the rear.)



Arrange the disc-driver on the tray on the cart again. Mark his position.

Explode the spring against the barrier as shown by giving the pin a sharp tap with a block of wood.

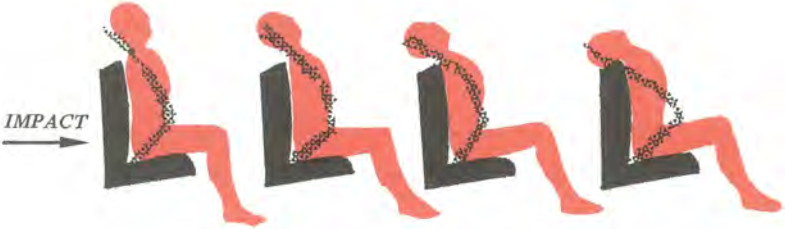


3.7 What happened to the disc-driver when the cart was suddenly moved forward? Try to account for this. Use the word 'inertia' in your description.

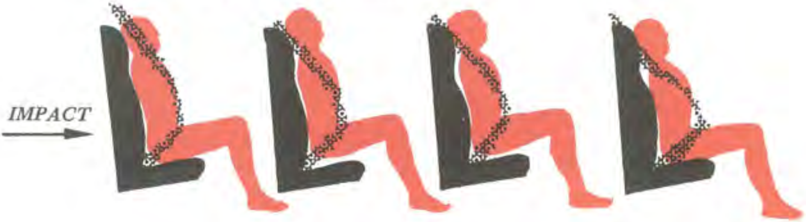
Activity 2 continued next page

If a car is struck from behind and is suddenly pushed forward, the driver tends to move in the same way as the disc did in Activity 2. However, a human being is not a unit like a disc. A human being consists of many parts which can move (to some extent) independently.

Look carefully at the first diagram below to see what happens when the head has no restraint. Initially, the torso is moved forward by the back of the seat, but the head is left behind just as the disc was. The driver's head does not start to move forward until his torso and seat have already moved forward a considerable distance. The effect is like that of cracking a whip. As a result, when a car is struck from behind, a driver may suffer a serious neck injury called whiplash injury.



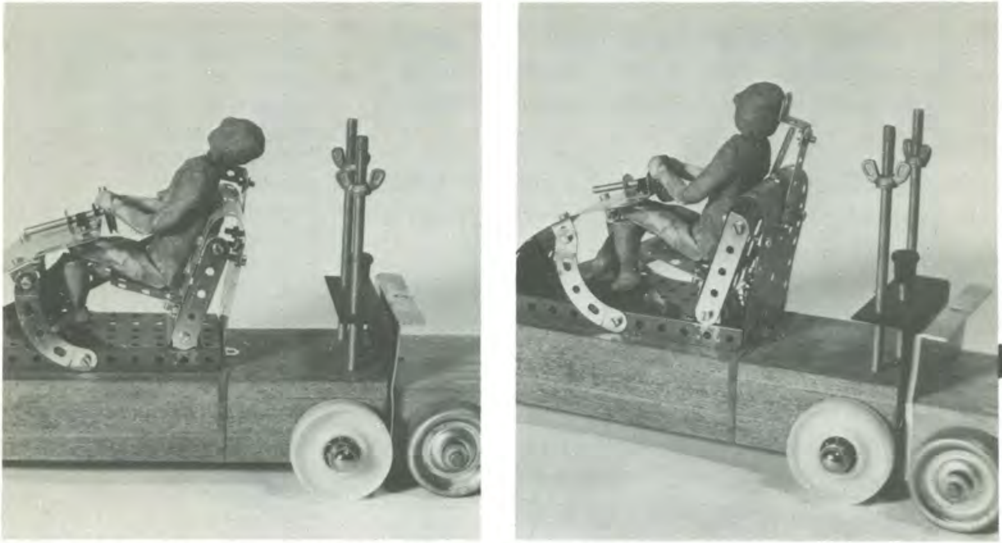
If the head is supported by a head restraint attached to the seat, both body and head are moved together.



A firm head restraint reduces the chances of serious injury to the neck in this type of collision.

You may like to make a model car and driver as shown in the photo at the top of the next page to study the effects of a head restraint.

If you do, demonstrate your model to the class.



The driver is a plasticine model. In both cases the cart has been struck from the rear. The photo at left shows the effect when there is no head restraint.

3.8 If you have time, you could try the effect on the car and the driver of a collision from the side.

3.9 Many physics texts give examples of inertia. List as many as you can find and add to the list from your own experience.

The driver used to be a drag driver. He sure makes us move to the back of the bus when he starts
WOOP WOOP

ACTIVITY 3: TWO CARTS

You have found that inertia is important when you try to start, stop or change an object's speed (or direction of motion). A better understanding of inertia could help a person to become a better driver.

You could work on the floor if a suitable table isn't available. However, you will have to devise a way of setting up the barriers.

If there is sufficient equipment, work in groups of two. If not, form larger groups and take turns using the equipment.

You will need:

- 2 carts with spring bumpers and starter pins
- various loads, e.g. bricks wrapped in plastic or tins filled with sand
- 2 barriers, e.g. 2 stout planks
- 1 spirit level–to be shared
- 4 G clamps
- 1 flat table, about 1.5 m long
- 1 metre ruler.

1 Use a spirit level to make sure that the table is level.

2 Clamp the barriers to the ends of the table. Use a clamp at each end of each barrier.

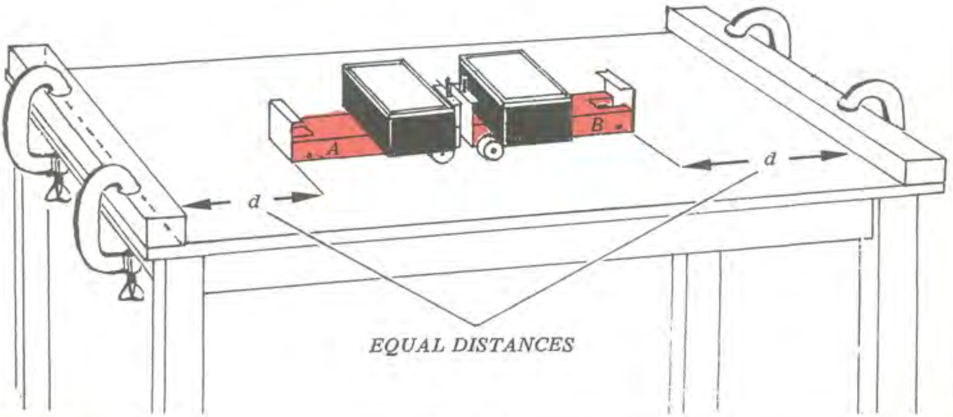
3 Mark one cart 'A', the other 'B'.

4 Load the spring as shown on page 45.

5 Put a load on each cart. One member of the group can do this. One cart will need to have a much greater load than the other.

Note: *At least one other member of the group will need to be observer and not know which cart has the greater load. Because of this it may be necessary to use containers for the loads. Make sure the containers are identical.*

Put the carts front to front, between the two barriers. The distance between the end of each cart and the barrier should be the same.



A sudden (explosive) force will come from a spring which has been compressed and suddenly released. This force will become the starting force.

Release one spring by giving the pin in cart A a sharp tap as shown on page 45.

3.10 What happened to the two carts?

☐ Did they hit the barriers simultaneously, or did one cart hit first? Which one? (You can probably judge more easily by sound than by sight.)

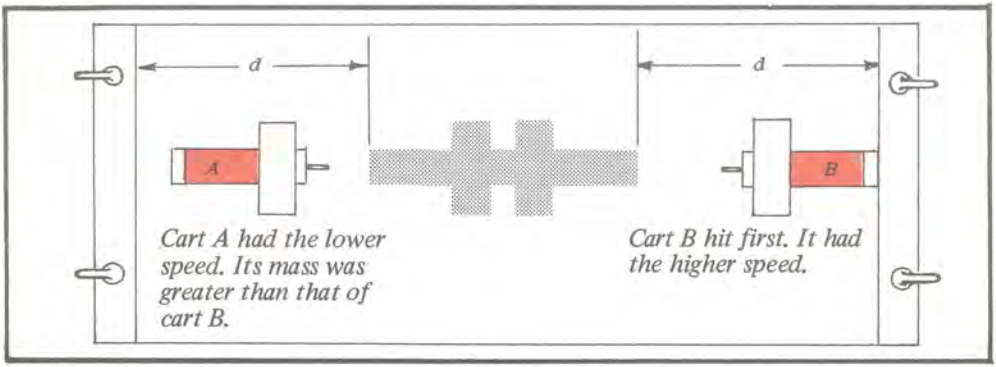
☐ The observer can try to guess which of the two loaded carts, A or B, is more massive. He can lift the carts to check his guess.

☐ Are the unloaded carts equally massive?

Another way of stating that one loaded cart, say A, is more massive than cart B is: the mass of cart A is greater than the mass of cart B.

3.11 You could repeat Activity 3 using different loads. You could also switch loading and observing roles within your group. Write an account of your investigation. Try to explain the relationship between mass and inertia.

3.12 Write a short report about the differences between the performance of a family car when it is loaded up for a holiday and when it has little or no load. You could mention the effect on starting, stopping and overtaking. Before you write your answer, you could discuss this question with the driver of a family car.



Cart A and cart B travelled the same distance; the one with the higher speed hit first.

Cart A had the lower speed. Its mass was greater than that of cart B.

Cart B hit first. It had the higher speed.

DEFINITION

Keep in mind that the spring which exploded between cart A and cart B gave them equal pushes. The same force acted on both for equal times.

The product of a force (F), and the time (t), during which it acts (F x t) is called **impulse**. The meaning is precise and quite different from the everyday use of the terms 'impulse' and 'impulsive'. Can you see that there is a connection between the scientific meaning and the everyday meaning?

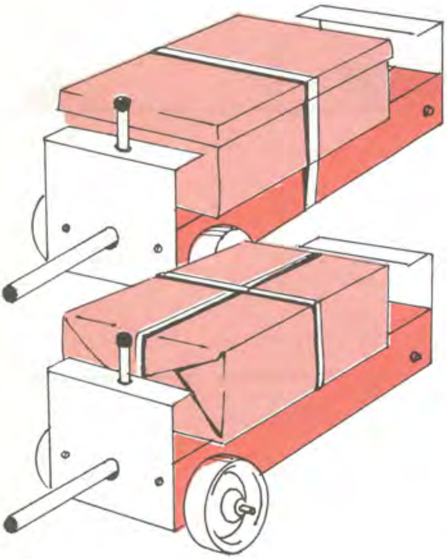
Here is a method you can use to calculate the impulse given to an object.

Suppose a force of 10 newtons acts on the object for 5 seconds. The impulse given to the object can be calculated as follows:

Impulse = force x time
= 10 newtons x 5 seconds
= 50 newton–seconds.

So far you have found that a force (an explosion) was necessary to start the carts–they remained stationary (at rest) without a force. A force was necessary to stop the moving masses, and a force is needed to speed the carts up or to slow them down. Try it out if you are not convinced.

ACTIVITY 4: MORE COLLISIONS



You will need:

- 2 carts with spring bumpers and starter pins
- different loads, e.g. boxes filled with sand or bricks wrapped in plastic bags.

You can design your own procedure which will enable you to answer questions such as:

☐ If a lorry, without brakes, collides with a small stationary sedan,

1) will both move, or only one?
2) will one rebound?
3) does what happens depend on the speed of the moving vehicle?

☐ What happens to the passengers in a head-on collision?

☐ What happens in a glancing collision?

You may have other questions which you would like to investigate.

✍ 3.13 State the question and the planned procedure for your investigation in your notebook before beginning each time. Report all your findings.

If a linear air-track or a mini-track is available, you can perform your tests using gliders carrying different loads.

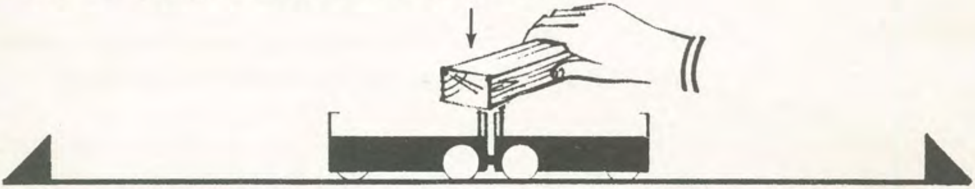
In the United States crash barriers and bumpers which are made of heavy plastic filled with water have been tested. In a crash the water is forced out and this makes the impact much less severe.

ACTIVITY 5: EXPLODING SPRINGS

You may want to find out more about forces interacting and report on your findings.

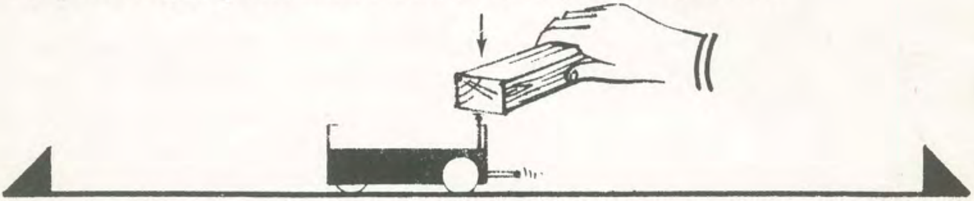
You will need the equipment from Activity 3 (Two Carts).

Explode springs in both carts simultaneously.



Explode a spring against a barrier.

Explode a spring when there is no other object near the cart.



Exploding springs exert forces which act on the carts for a short time (impulses).

3.14 Here are some questions you could try to answer in your report.

☐ Do two springs appear to have twice the effect of one?

☐ How does the behaviour of a cart exploded against another cart (using one spring), differ from a cart exploded against a barrier?

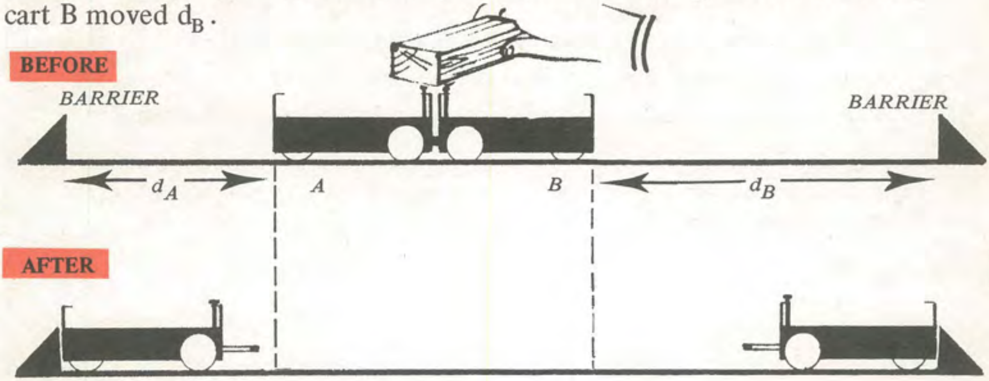
☐ Describe the behaviour of one cart when the spring is exploded with no other object near it.

You can check your answers to some questions by turning to page 104.

ACTIVITY 6:

A CALCULATION–FOR THOSE WHO LIKE MATHEMATICS

Suppose carts A and B are loaded with different masses and their starting positions are adjusted, so that when they are exploded they strike the barriers simultaneously. Call the distance which cart A moved d_A and the distance cart B moved d_B.



Both carts A and B moved for the same time (t) from the moment of explosion to the moment of being stopped by the respective barriers.

$$\text{average speed} = \frac{\text{distance moved}}{\text{time taken}}$$

The time for each cart was the same, call it t seconds. The average speed of cart A can be expressed:

$$v_A = \frac{d_A}{t}$$

The average speed of cart B can be expressed:

$$v_B = \frac{d_B}{t}$$

And it follows that:

$$\frac{v_A}{v_B} = \frac{d_A}{d_B}$$

This can be stated in words: the distances covered during the same time interval are in the same ratio as the average speeds.

Which cart moves with higher average speed after explosion–the one with the greater mass or the one with the smaller mass?

If you are not sure what answer to give to this question, try it out by putting more and more loads on cart A and finding starting points from which the carts hit the barriers simultaneously.

TEST YOURSELF–COLLISIONS

Answer the following questions in your notebook.

1 Car I is identical to car II except that car I has more massive wheels. Which one of the following statements about the inertia of the cars is correct?

A The inertia of car I is greater than the inertia of car II.

B The inertia of car I is smaller than the inertia of car II.

C The inertia of car I is equal to the inertia of car II.

D It is not possible to compare the inertia of the two cars without additional information.

2 A force of 5 newtons acts on a cart for 2 seconds. What is the impulse of the force in newton-seconds?

A 10

B 7

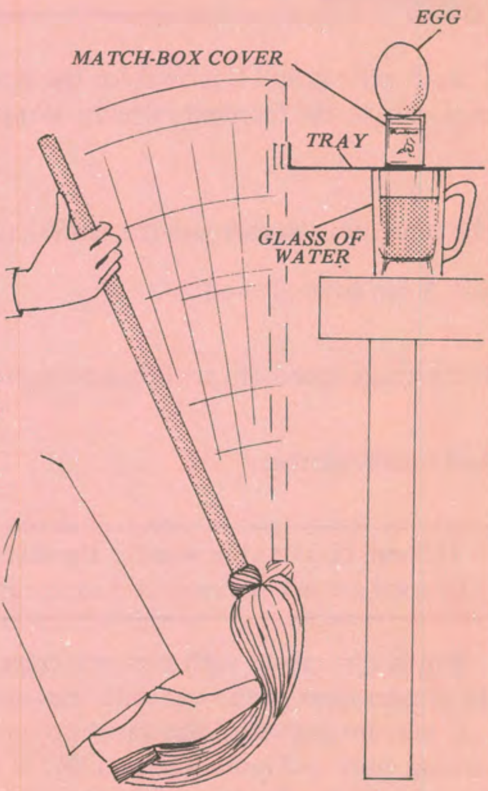
C 5

D 2.5

E 2

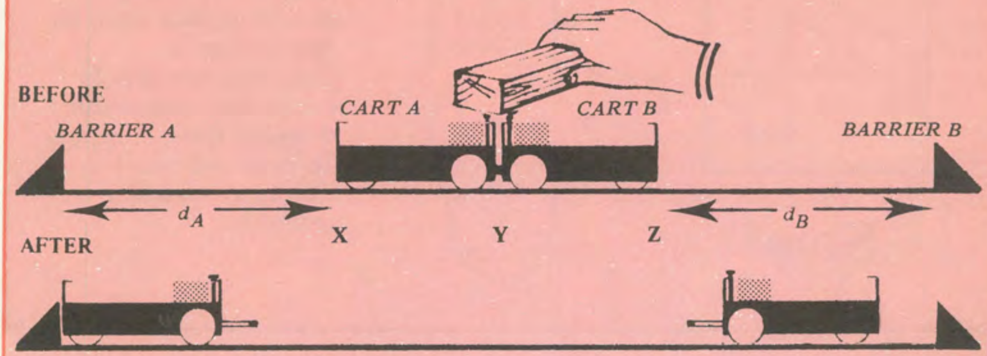
3 Tony arranged a glass of water, a light metal tray, a match-box cover and an egg on the edge of a kitchen table, as shown in the diagram.

He placed his foot on the straw of a straw broom and pulled the handle back. When he let the handle go, it struck the tray with a very strong force, which sent the tray to the other end of the table. The edge of the table prevented the handle from hitting the glass of water. What happened to the egg? Well, it plopped into the glass of water. Explain this surprising result.



Questions 4 and 5

Two small carts, A and B, are arranged on a table top as shown below.



average speed of cart A $v_A = \frac{d_A}{t}$ average speed of cart B $v_B = \frac{d_B}{t}$

4 The spring bumpers of the carts are released and the carts 'explode' away from each other. Cart A hits barrier A before cart B hits barrier B. Which cart has the greater mass?

5 The carts can be placed together at a certain position so that, on 'exploding' apart, they reach the barriers at the same time. It is found that this occurs if the centre of the carts is placed at one of the positions X, Y or Z. Which one of these three positions would this be?

---

6 When the driver of a fast-moving car brakes hard suddenly, objects in the car tend to

- A continue to move forward.
- B remain in place in the car.
- C be thrown out of the car sideways.
- D be forced toward the back of the car.

7 What happens to a person seated in a stationary car when the car is jerked forward suddenly by being hit from behind?

8 Two billiard balls rest on a billiard table. One of the balls is unusual in that it has a metal centre and this makes it more massive than the other ball. How could you find out which ball has the greater mass, if you were not permitted to lift the balls from the table?

Now turn to Check Your Answers on page 104.

OPTION 4

Stop!

In terms of transport safety it is as important to be able to stop a moving vehicle as to be able to start it. This option will help you to find out about stopping time, stopping distance and the effects of stopping suddenly.

Imagine you are driving a car, and a child runs across the road. How much time does it take to stop? What is the smallest distance which the car travels during this time interval? A great deal has to happen before the car stops.

1 Your eyes notice the child, and a message travels to your brain. This can be called **perception time.**

2 Your brain sends out the signal 'stop', which triggers the muscles of your foot. The foot starts toward the brake pedal and then pushes it down.

Time intervals 1 and 2 together are often called **reaction time.**

3 As soon as the brake starts to grip, the car slows down, but it will not stop 'on the spot', as some drivers claim.

ACTIVITY 1: REACTION TIME

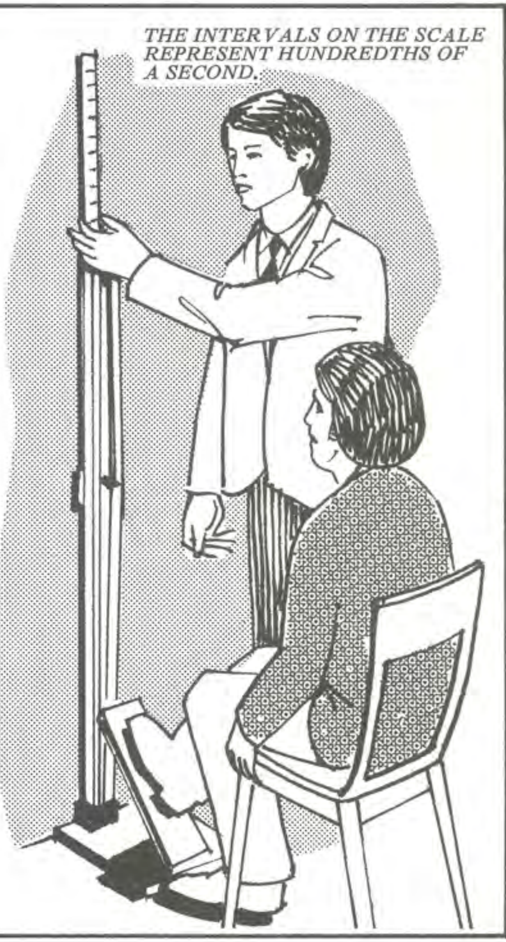
Here is a way of making a simple foot-brake and using the brake to test your reaction time.

You will need:
- 1 metre ruler
- paste
- 1 time scale–to paste to the ruler
- 1 brake device reaction timer.

Sit down in front of the brake and rest your foot lightly on the brake.

Look at the ruler held by your partner, who will let the ruler fall without warning. (Your partner should let the ruler drop straight down.)

The moment you see the ruler drop step on the brake pedal as quickly as you can.



THE INTERVALS ON THE SCALE REPRESENT HUNDREDTHS OF A SECOND.

Another Method

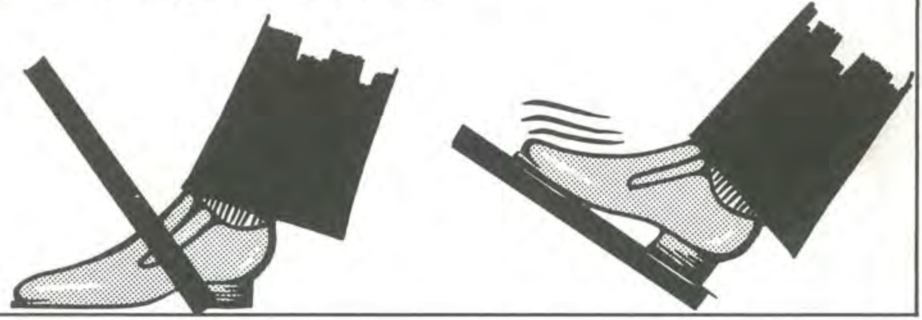
If a braking device isn't available, you could catch the taped ruler which a partner drops. You may design a different reaction timer.

4.1 Record in a table in your notebook the distance the ruler fell. Repeat this several times and take the average of these readings.

If the ruler falls freely, the distance it fell can be used as a measure of reaction time, which can be read off the timing strip on the ruler. The **reaction time** includes the time for the eye to notice that the ruler has started to fall, for the signal to race to the brain, for the command 'push the pedal' to reach the muscles of the foot, and for the foot to move and then push the pedal.

Activity 1 continued next page

4.2 Now rest your foot on the floor next to the brake pedal, and find your reaction time again. Repeat this several times and take the average. Now compare the two results.



In these testing situations you expected the ruler to fall. In a real traffic situation your reaction time would probably be longer.

To illustrate the distractions a driver would encounter in real traffic situations, you may like to find your reaction times under varying conditions.

4.3 Report on all your findings. To help you make your report, you could ask your partner to:

- ☐ talk to you while you are being tested,
- ☐ play a radio, and/or
- ☐ flash lights.

You may also want to find your reaction time before and after exercise or sport activities.

If a stop-watch is available, you could find the reaction time of pedestrians and drivers waiting for the change of a traffic light.

Stopping and Work

During the reaction time interval when you were testing with the brake device (i.e. to the moment the brake acted) the imaginary car travelled over a distance without changing speed.

For instance, with a reaction time of 1 second and a speed of 120 kilometres per hour (probably top legal speed in most States) the car travels more than 30 metres.

Average speed: $v = \frac{d}{t}$

Hence: $d = v \times t$

If $v = 120$ km/h and $t = 1$ s

$$d = \frac{120 \text{ km}}{1 \text{ h}} \times 1 \text{ s}$$

$$= \frac{120 \times 1000 \text{ m} \times 1 \text{ s}}{60 \times 60 \text{ s}}$$

$$= 33 \text{ m (to the nearest metre).}$$

Thirty-three metres is probably three times the length of a science room or about six car lengths– and the brake hasn't even been applied yet!

When the brake starts to grip, the car loses speed and finally stops. The braking force does not stop the car on the spot. It has to act over a distance (the braking distance). Work must be done to stop a moving object.

Work can be defined as the **force** multiplied by the **distance.** The force exerted by the brakes cannot increase beyond a value which depends on the brakes and on the conditions. The distance will therefore depend on the work which must be done to stop the car.

4.4 Which factors determine the work required to stop the car?

Suppose you are running and then try to stop suddenly. You usually find that the faster you run, the greater the distance you need to stop. You would therefore expect speed to have something to do with the work required.

ACTIVITY 2: SPEED AND STOPPING DISTANCE

You can do Activity 2 with or without a bicycle.

WITHOUT A BICYCLE

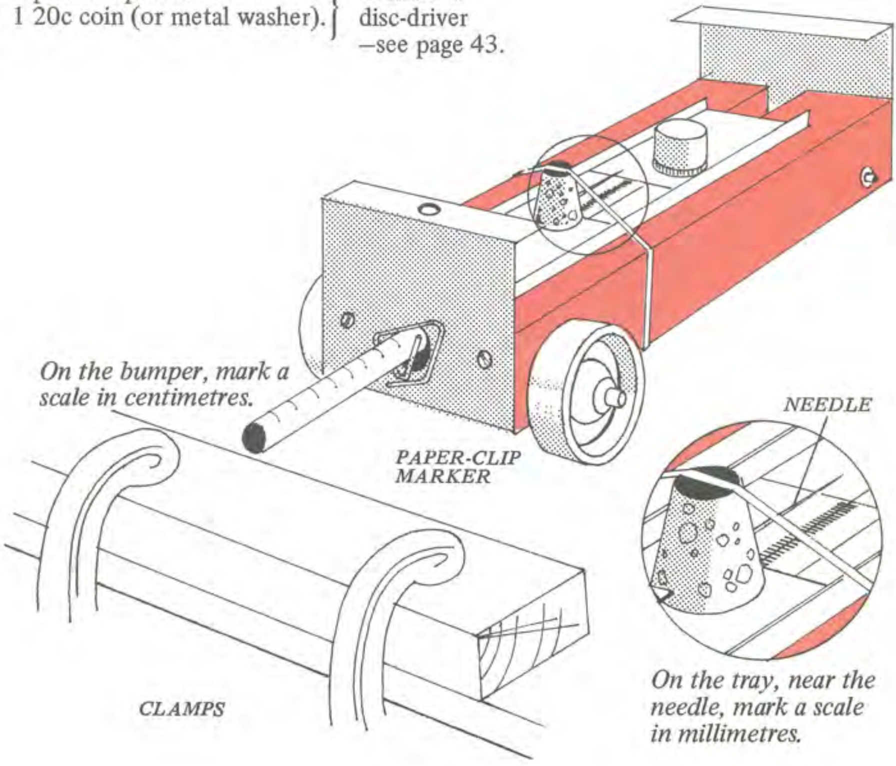
You can work on a table, or on the floor.

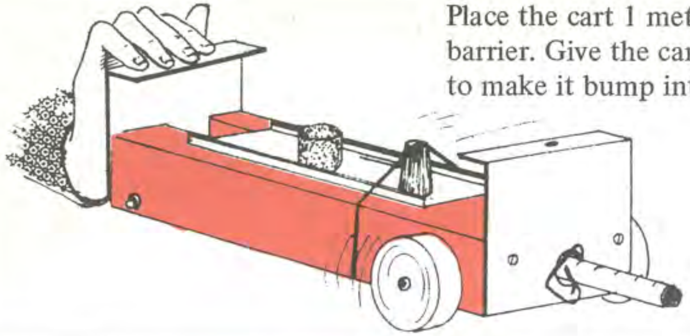
If you are working on a table, you will need:

- 1 cart with a spring bumper
- 1 marker which will move easily over the bumper bar, e.g. a paper-clip opened as shown in the diagram below
- 1 barrier
- 2 G clamps
- 1 cardboard tray, about 20 cm x 5 cm, with side edges bent up
- 1 needle stuck through a cork stopper–to simulate the steering column
- 1 rubber band–to hold the cork stopper
- 1 piece of plasticine } to make a disc-driver –see page 43.
- 1 20c coin (or metal washer). } to make a disc-driver –see page 43.

If you are working on the floor, you will need everything listed at left, but you will need to work out a way of setting up the barrier. You may have to use something other than the barrier held with the G clamps.

If you don't have a table, and you can't set up a barrier on the floor, you could push the cart against a wall.

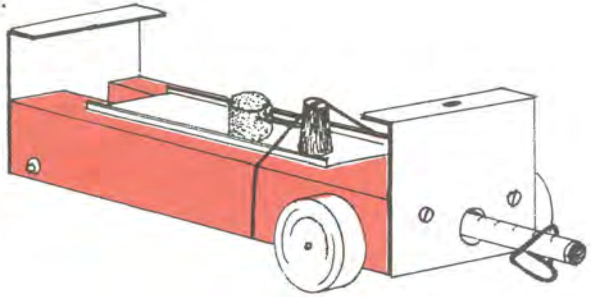

On the bumper, mark a scale in centimetres.
NEEDLE
PAPER-CLIP MARKER
CLAMPS
On the tray, near the needle, mark a scale in millimetres.



Place the cart 1 metre in front of the barrier. Give the cart a push, sufficient to make it bump into the barrier.

If a force-measurer is available, you could use it to push the cart.

4.5 In a table record the depth to which the needle (steering column) penetrated the plasticine (driver, who was not held back by a seat belt). Also, record the distance between the marker on the bumper and the cart.



Repeat this procedure, but with a harder push so that the cart moves faster. Compare the positions of the marker and the penetration of the needle in the two cases.

The marker moved because the spring was compressed when the cart collided with the barrier.

The marker lets you see by how much the spring was compressed. The more the spring is compressed, the greater the work which has been done in stopping the cart.

4.6 You could report on what you have found out about the speed of the cart and the work needed to stop it.

□ How is this related to damage to cars and injuries to drivers when cars are stopped suddenly?

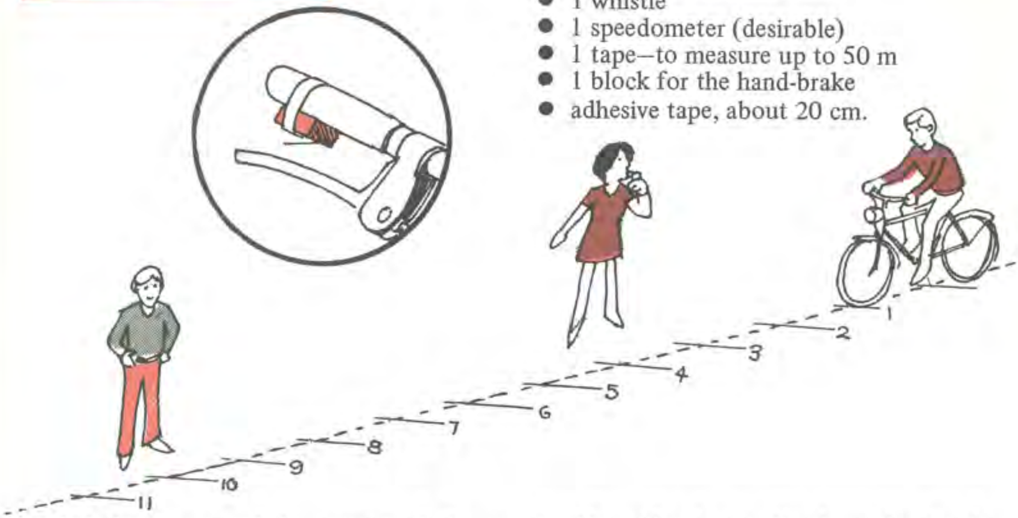
□ Comment on the slogan: 'Speed kills'.

Activity 2 continued next page

WITH A BICYCLE

You will need:

- 1 bicycle with hand-brake
- 1 whistle
- 1 speedometer (desirable)
- 1 tape—to measure up to 50 m
- 1 block for the hand-brake
- adhesive tape, about 20 cm.



It is best to work in groups of three: a rider, a signaller and an observer-recorder.

For applying a stopping force only the hand-brake will be used—make sure that it is in good order.

To make sure that the brake always exerts the same force, a block can be fixed under the handle-bar as shown in the insert.

1 Mark out a testing track—a straight line—20 to 30 metres long and mark it off in metres.

2 The test rider rides the track at a steady speed—about 2 metres per second (approximately 7 kilometres per hour). This would be easiest to measure with a speedometer, but you may think of another method.

3 The signaller blows the whistle, the rider brakes and the observer notes the position of the front wheel at the moment of braking.

4 The rider keeps the bicycle steady when he has come to a stop, so that the observer can note the new position of the front wheel when the rider has stopped. The observer then calculates the total stopping distance (d).

Repeat steps 2 to 4, but at twice the speed—4 metres per second (about 15 kilometres per hour).

What is the connection between speed and stopping distance? Calculate how far the rider travelled during the reaction time (d_R). You could either assume a reaction time of 0.5 seconds or you could use a rider whose reaction time has been measured in Activity 1 (Reaction Time), page 57. Call this distance the reaction distance. Then $d_S = d - d_R$ where d_S is the stopping distance due to speed alone. Now compare this corrected stopping distance with the speed before applying the brake.

ACTIVITY 3: MASS AND STOPPING WORK

Here you can find out which is harder to stop at a given speed–a more or less massive cart. You can do this with either one cart or two.

First fix the barrier firmly with the two clamps to the bottom edge of the table. Next mark a start line near the 'top' of the tilted table.

You will need:

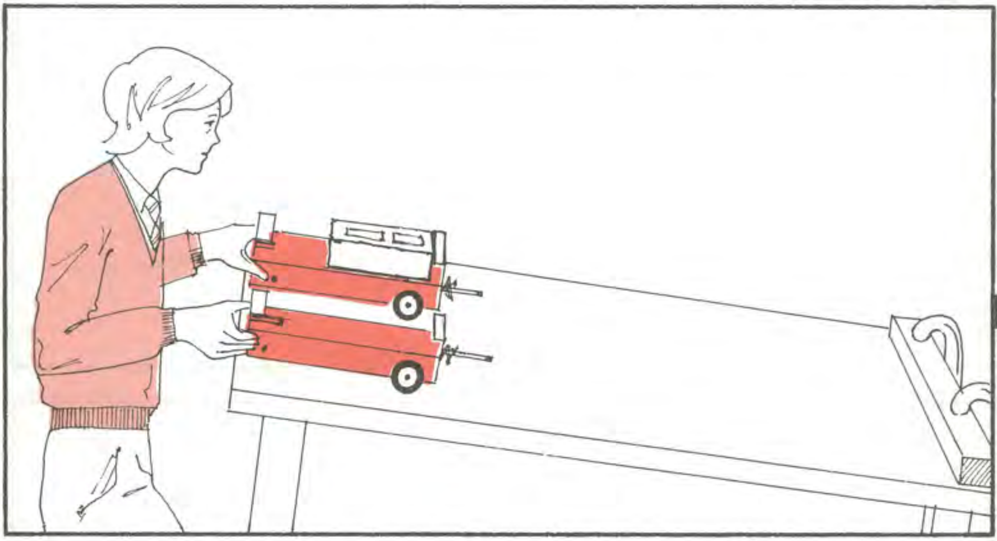
- 2 identical carts with spring bumpers and markers
- 1 brick (or other large mass)

or

- 1 cart with a spring bumper and a marker
- several different masses.

You will also need:

- 2 G clamps
- 1 barrier
- 1 force-measurer, 50 N (optional)
- 1 table, 1.5 m long, which can be raised at one end.



If you are using one cart with different loads, adjust the marker on the spring bumper to its zero position (just touching the end plate of the cart).

Load the cart with one of masses and release it from the start line. After the collision measure and record the distance the marker has moved.

Repeat with different masses. Each time note the distance the marker is moved by the collision, and note the total mass (cart plus load).

If you are using two identical carts, one should be loaded with a brick (or other large mass), the other should be unloaded. Release them together from the start line. Note the distance the markers are moved by the collision.

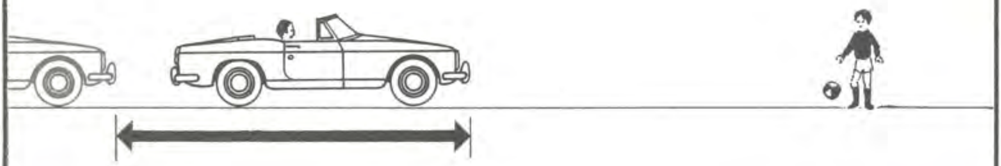
4.7 Whichever method you used you can now answer the question: How does an increase in mass affect the amount of work (as measured by the marker) required to stop the cart?

SUMMING UP

The distance needed to stop a moving car can be considered in two parts: the reaction distance and the braking distance.

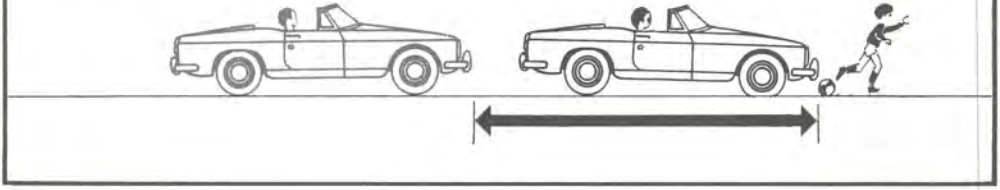
1 **Reaction distance.** This is the distance a car travels between the moment when the driver sees the need to stop and when he actually brakes. During this period the car continues to move forward with its speed unchanged. How far it travels depends on its speed and the reaction time of the driver. The reaction time of the driver depends on factors such as:

- ☐ concentration (tiredness, distractions),
- ☐ drugs (alcohol, tranquillizers),
- ☐ experience,
- ☐ age, etc.



2 **Braking distance.** This is the distance a car travels while the brakes are slowing it to a stop. Braking distance depends on factors such as:

- ☐ the speed,
- ☐ the efficiency of the brakes,
- ☐ the force acting on the brakes,
- ☐ the type of road surface,
- ☐ the type and condition of the tyres,
- ☐ the area of tyre in contact with the road, and so on.



(You can find out more about tyres and road surfaces in Option 7.)

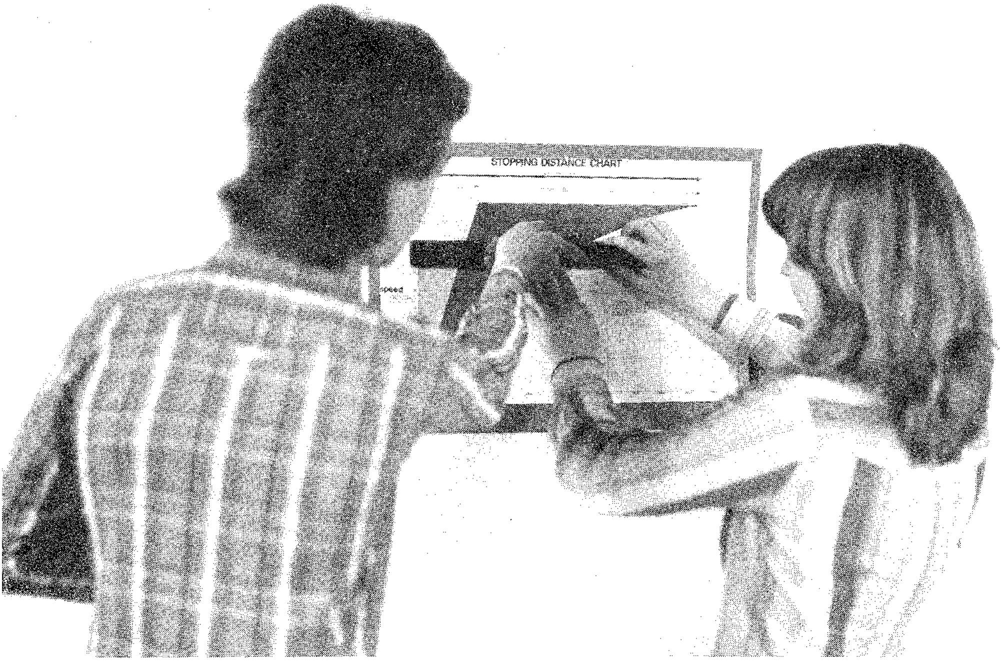
TABLE OF STOPPING DISTANCES

Note: *All figures are given to the nearest whole number. Because of this the total stopping distance may vary slightly from the sum of the reaction distance and braking distance.*

SPEED IN KILOMETRES PER HOUR	SPEED IN METRES PER SECOND	REACTION DISTANCE IN METRES	BRAKING DISTANCE IN METRES	TOTAL STOPPING DISTANCE IN METRES*
8	2	2	1	3
16	4	3	3	6
24	7	5	4	9
32	9	7	6	13
40	11	8	9	17
48	13	10	12	22
56	15	12	16	28
64	18	13	22	35
72	20	15	28	43
80	22	17	36	53
88	24	18	45	64
96	26	20	55	76
104	28	22	67	89
112	31	23	81	105

* Average distances for an alert driver (reaction time 0.75 second) on a dry sealed road in a car in good condition.

Adapted from figures based on tests made by the Bureau of Public Roads USA.



Look at the Stopping Distance wall chart showing the relationship between speed and stopping distance. It shows that as the speed of a vehicle increases the total stopping distance increases very quickly. It also shows that at higher speeds the distance travelled during the reaction time before the brakes are applied becomes greater than at lower speeds.

Reaction time becomes even longer if the driver's reactions are impaired by sleeplessness, alcohol or other drugs.

It is vitally important to keep a safe distance between your car and the car in front at all times when you are driving.

If you have not chosen Option 3, you might like to do Activity 4 here.

ACTIVITY 4: WAYS OF MAKING SAFER CARS

This activity should be essentially your own design. One thing you could perhaps investigate is why some cars have collapsible fronts.

If a car collides with a haystack, the car loses its energy slowly. The damage to the car is far less than it would be if the same car were to crash at the same speed into a brick wall. Similarly, if the front of a car crumples in a collision, the car loses energy more slowly than it would had the front remained rigid on impact.

You could test this by 'crashing' a cart with the front as it is (rigid) and with a front that would be likely to crumple on impact.

You could use aluminium foil bumpers, or plasticine front ends, or any other similar type of attachment for a collapsible front.

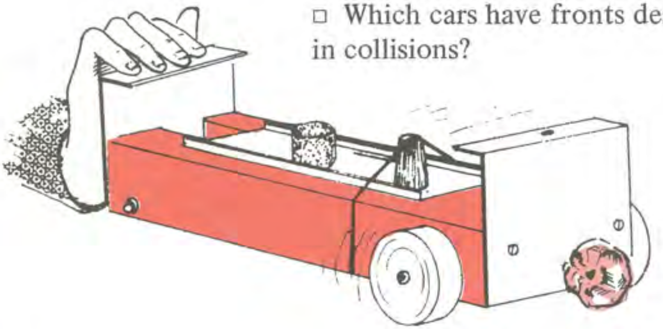
Set the cart off with the different bumpers–but always at the same speed–and assess the damage.

4.8 Make a note of your plan and the outcomes of your tests in your notebook. You could try to find out the answers to the following questions.

☐ Are the bumper bars on many cars merely an ornament?

☐ How are aircraft, landing on a carrier, stopped?

☐ Which cars have fronts designed to collapse in collisions?



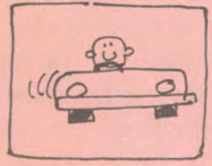
You can check your answers to some questions by turning to page 106.

TEST YOURSELF–STOP!

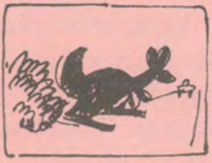
Answer the following questions in your notebook.

Questions 1 and 2

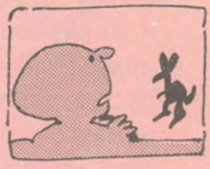
The cartoon strip below shows a sequence of events which happened to Flash when driving in the country.



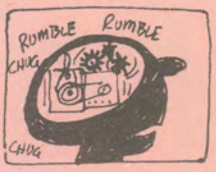
1 *Flash is on a pleasant Sunday drive.*



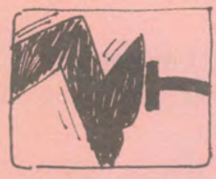
2 *A kangaroo bounds out from behind a bush.*



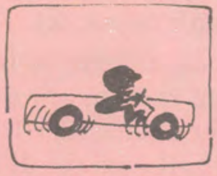
3 *Flash sees the kangaroo.*



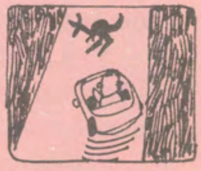
4 *What will Flash do?*



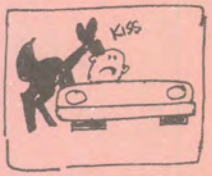
5 *Flash presses the brake pedal.*



6 *The brakes act to slow the wheels.*



7 *Flash's car skids along the road.*



8 *The car stops. Phew!*

1 Flash's reaction time is the time which begins with the event shown in

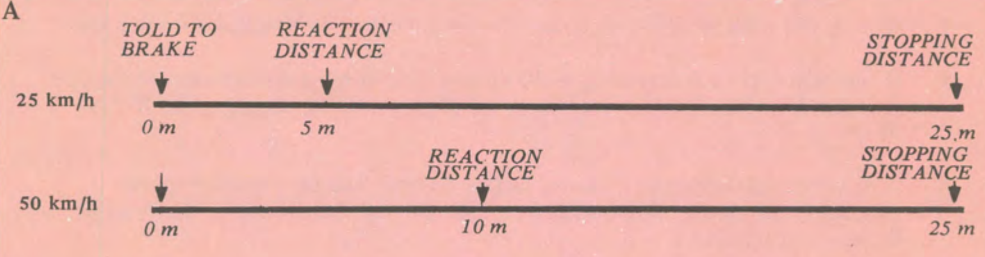
- A picture 2 and ends with the event shown in picture 5.
- B picture 3 and ends with the event shown in picture 5.
- C picture 2 and ends with the event shown in picture 6.
- D picture 2 and ends with the event shown in picture 7.
- E picture 3 and ends with the event shown in picture 6.

2 The braking time of the car is the time which begins with the event shown in

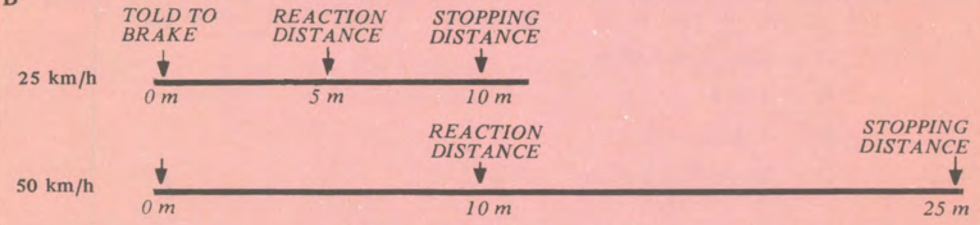
- A picture 4 and ends with the event shown in picture 5.
- B picture 4 and ends with the event shown in picture 6.
- C picture 3 and ends with the event shown in picture 8.
- D picture 6 and ends with the event shown in picture 8.
- E picture 5 and ends with the event shown in picture 6.

3 Two drivers with the same reaction time take part in a braking test. The car is driven first by one driver at 25 kilometres per hour, and then by the other at 50 kilometres per hour. One of the diagrams below shows the record of the actual reaction and stopping distances. Which one?

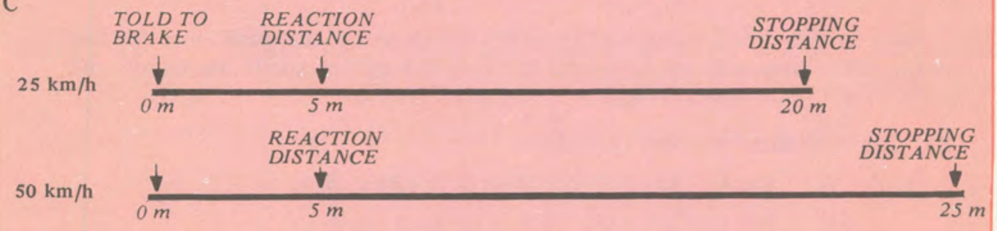
A



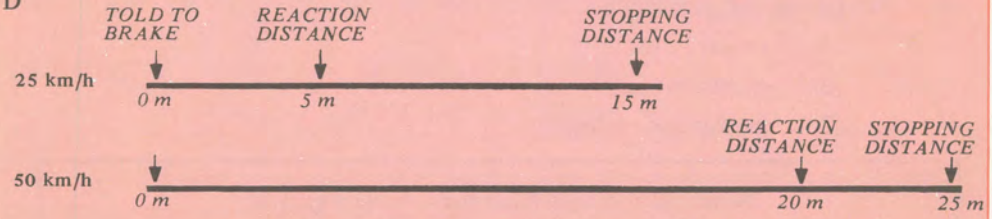
B



C



D



Test Yourself continued next page

Questions 4–7

These questions refer to the wall chart of stopping distances, or the table of stopping distances on page 65. Assume, unless otherwise stated, that the conditions are the same in the situation described in each question as they were when the stopping distances were measured.

4 What is the total stopping distance of a car travelling at 40 kilometres per hour?

5 If the driver of a car travelling at 40 kilometres per hour is distracted so that his reaction time becomes 1.5 seconds, what then would be the stopping distance of the car?

6 A driver brakes hurriedly to avoid hitting a child. The car's total stopping distance is 76 metres. What is the best estimate for the car's speed before the brakes were applied?

7 An alert test driver of a car travelling at 88 kilometres per hour doubles his speed to 176 kilometres per hour. Which one of the following is the most likely total stopping distance of the car when travelling at 176 kilometres per hour?

A Less than 128 m

B 128 m

C 140 m

D More than 140 m

Questions 8 and 9

Two identical cars travelling at the same speed crash into different obstacles. Car I crashes into a brick wall and is brought to a stop in 6 metres. Car II crashes into the back of another car and is brought to a stop in 20 metres.

8 The work done in stopping car I was

A greater than the work done in stopping car II.

B less than the work done in stopping car II.

C the same as the work done in stopping car II.

9 The damage will probably be

A greater to car I.

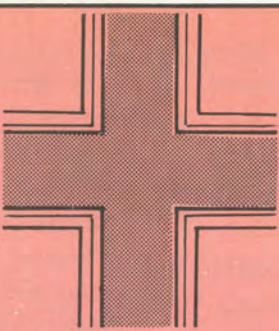
B greater to car II.

C the same to both cars.

Now turn to Check Your Answers on page 106.

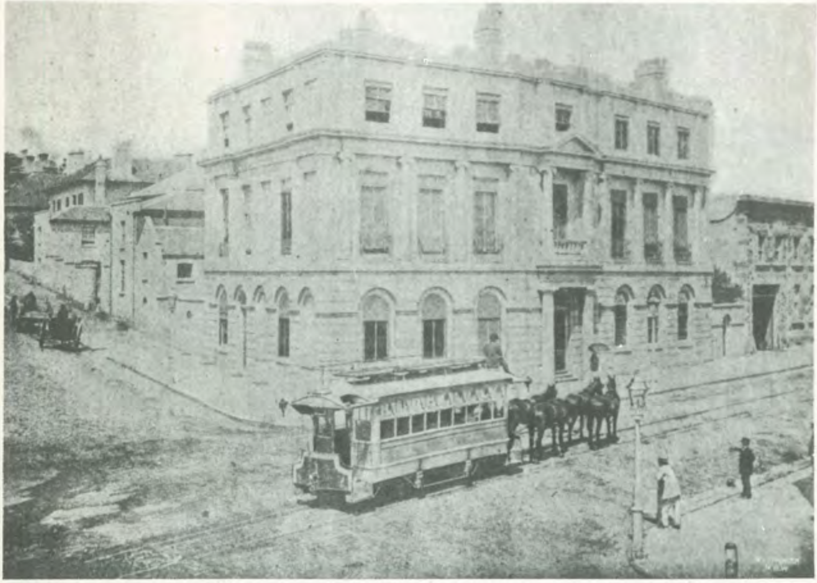
OPTION

5



This option describes the effects that intersections have on traffic flow, and describes some ways to investigate these effects.

Intersections



A horse tram-car, 1862, corner Pitt and Hunter Streets, Sydney.
(Photo by courtesy of New South Wales Government Printer.)

Does the photo above show why road accidents were rare in the early days of Australia? Compare it with the photos on pages 72, 73, 74 and 75.

Before the invention of the motor-car, fewer vehicles used the roads. Horses and carts moved more slowly than motor-cars. Once, when two vehicles met at an intersection the risk of collision was small, but now collisions occur frequently at intersections.

With increasing numbers of faster vehicles now using the roads, more collisions and delays occur at intersections.

There are several ways of reducing these problems.

If the traffic flow is light, collisions can be reduced by having 'priority rules'—that is, rules that tell drivers which vehicles may go first.

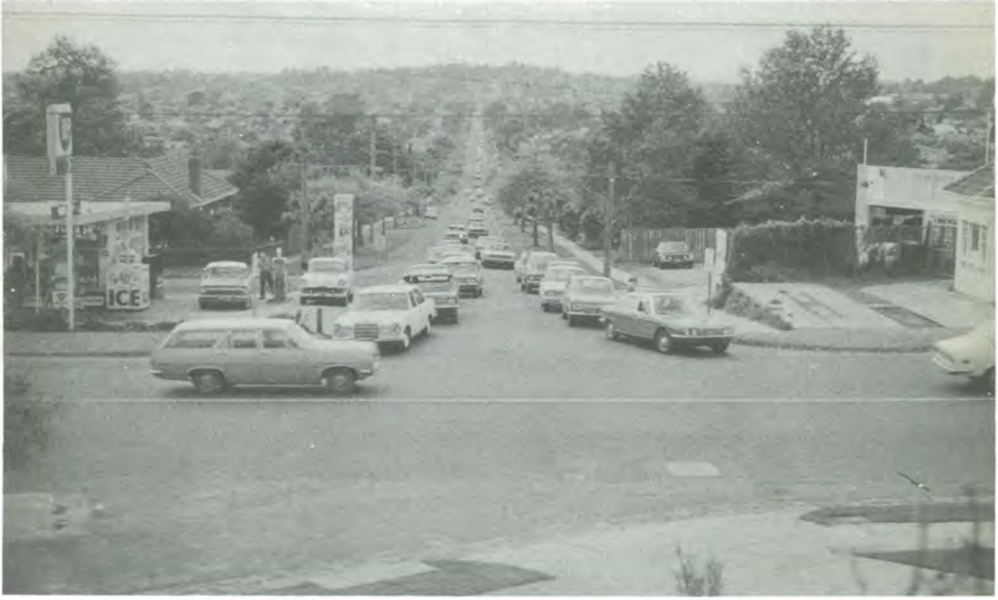
Find others doing this option and discuss with them:

☐ whether the 'give way to the right' rule is a good one,

☐ other rules used in Australia to decide who has priority at an intersection, and

☐ advantages and disadvantages of priority roads.

During the discussion your group could talk about the sign for a priority road. Is it the same throughout Australia?



The 'give way to the right' rule was operating at the intersection shown in the photo above. What problem has occurred as the result of this priority rule?

If the traffic flow is heavy, drivers have more things to notice and many decisions to make, particularly at intersections.

Several ways of reducing delays and collisions at busy intersections are used. These include intersections being designed so that conflicts are reduced, or controlled by traffic police or traffic lights. Another way is to separate streams of traffic travelling in different directions.

The roundabout at this intersection makes the traffic flow pattern simpler and reduces the number of decisions a driver has to make.

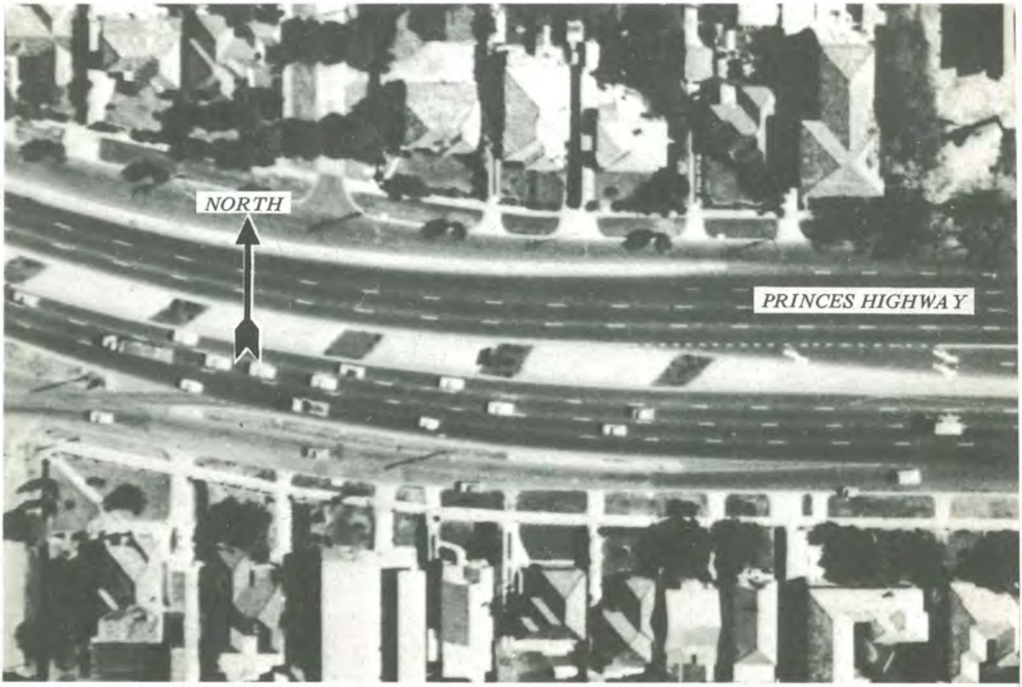
This traffic policeman is making decisions for the driver.

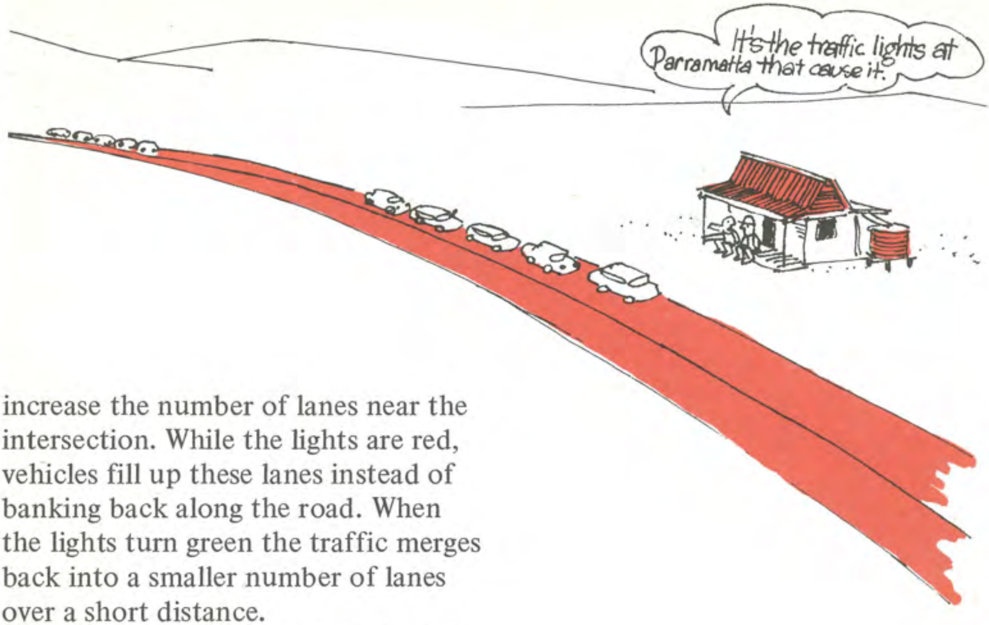
The photo above shows traffic moving at two separate levels. This is another way of reducing congestion and delays at intersections.

When an intersection is controlled, traffic can usually flow smoothly through it. Traffic lights are timed to allow the maximum rate of flow through the intersection. (Activity 3, page 78, describes a way of studying traffic lights.)

Sometimes traffic lights and policemen alone cannot solve traffic congestion. Sometimes it is necessary to reroute the traffic or to build an overpass or an underpass (as in the photo at left) so that traffic flows are separate and uninterrupted.

Another way of reducing traffic delays at busy intersections is to

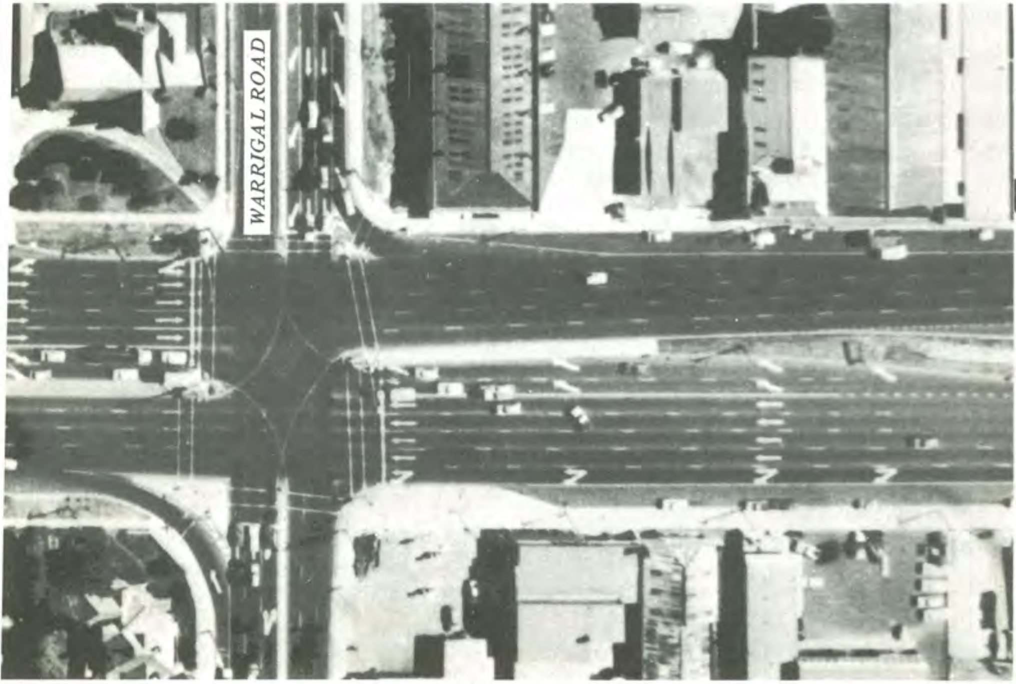



It's the traffic lights at Parramatta that cause it.

increase the number of lanes near the intersection. While the lights are red, vehicles fill up these lanes instead of banking back along the road. When the lights turn green the traffic merges back into a smaller number of lanes over a short distance.

The photo below shows additional lanes at the intersection of the Princes Highway and Warrigal Road in the Melbourne suburb of Oakleigh.

(Photo below by courtesy of Crown Lands and Survey, Melbourne. Crown (State of Victoria) Copyright.)



ACTIVITY 1: AN INTERSECTION PROBLEM

You may have an intersection in your school (where two or more corridors meet) which becomes crowded at certain times. If so, find a position where you can observe the intersection and try to describe what the problem seems to be, and what causes it.

Here are some suggestions to help you plan your investigation. You will probably need to:

☐ describe where the intersection is in the school.

☐ draw a sketch plan of it, showing its width and anything else you believe is a traffic hazard.

☐ find out what times, and for how long, the crowding lasts.

☐ find out how many people are involved. Where do they come from and where do they go? Several observers may be necessary to count the traffic entering and leaving the intersection from each direction.

If you can describe the problem, you may be able to suggest a solution. You may suggest:

☐ rerouting the traffic, or

☐ changing the time-table or school rules, or

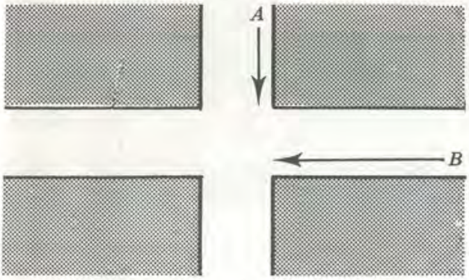
☐ redesigning the intersection.

5.1 Make a report of your findings and your recommendations.

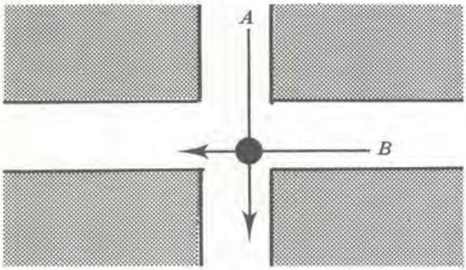
You may be able to find the **breakdown volume.** This is the number of students per square metre at which the delays become intolerable.

ACTIVITY 2: DESIGNING ROUNDABOUTS

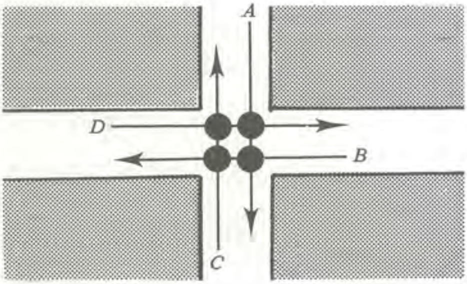
If car A passes through the intersection at the same time as car B, a collision could occur.



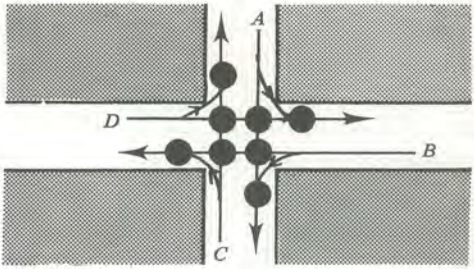
In other words, there is a **conflict** where the paths cross. Collisions can occur at conflict points.



If each road carries traffic in both directions, there are more places where collisions can occur.

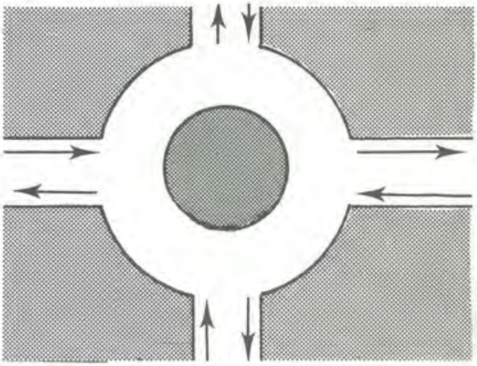


When left-hand turns are included, the number of conflicts increases.



5.2 Draw a plan of the intersection above and mark on it all possible right-hand turns. What is the **total number of conflicts** now?

One way to reduce the number of conflicts would be to install a roundabout at the intersection.



5.3 How many conflicts are still left? Discuss the advantages and disadvantages of installing roundabouts at intersections.

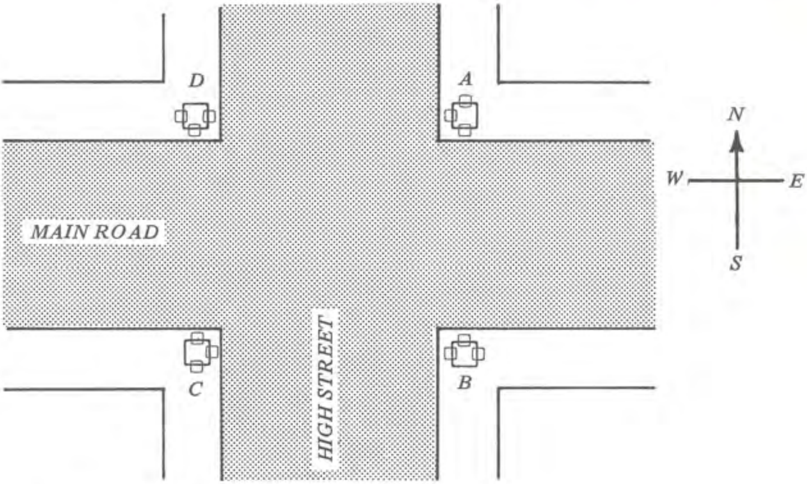
5.4 What other methods are available to improve traffic flow?

5.5 If there is a road intersection near your school, draw a plan of it and work out the number of conflicts. Try to redesign the intersection to reduce the number of conflicts.

ACTIVITY 3: TRAFFIC LIGHTS

Some students investigated traffic lights at an intersection. Here is how they went about recording their information.

1 They worked out what they needed to know about the intersection itself–and made a plan.

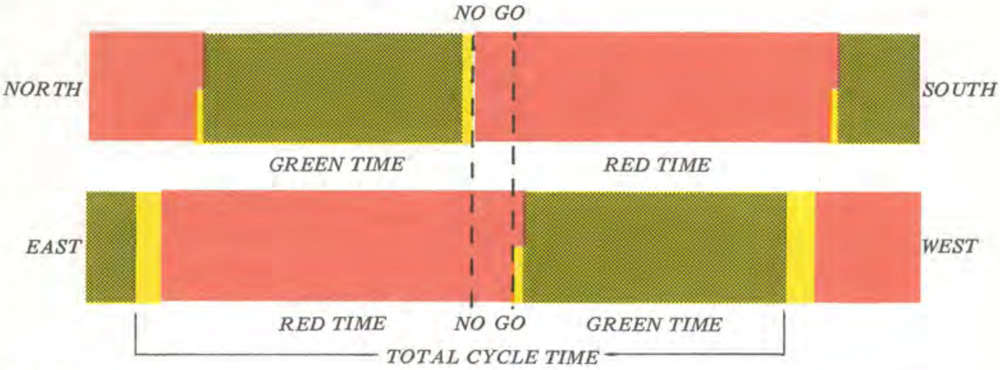


2 They timed the lights and recorded the times in tables.

	TIME IN SECONDS			
TRAFFIC DIRECTION	**A**	**B**	**C**	**D**
GREEN				
AMBER				
RED ONLY				
AMBER/RED				
TOTAL CYCLE				

DO NOT WRITE IN THIS TABLE

3 They displayed their results.



5.6 If there are traffic lights near your school, you could plan your own observations and prepare a report. For your report, you will also need to know how heavy the traffic is in each direction.

Then you could discuss the following questions.

☐ Is the 'green time' the same for each direction?

☐ If traffic is heavier in one direction than in another, does that direction have a longer 'green time'? Would you recommend any change in the proportion of 'green time' in each direction? If so, what change and why?

☐ What is the total 'cycle time' at the intersection? Do you think that this is too long or too short? What would be the advantages and disadvantages of a long or short 'cycle time'? You could record information about this last question in a table.

☐ Which two traffic colours of one green-amber-red set are on at the same time, if any? What is the purpose of showing these two colours at the same time?

☐ The lights are red for all traffic for a few seconds. Why?

FURTHER ACTIVITIES

You may like to find out if the 'green time' is long enough for a pedestrian to cross the road. Write a brief report of your findings.

You may be able to think of other observations to carry out.

When you write your report be sure to list any references you used. Two you could look for in a library are:

Huxtable, E.A. *Australian Driving Manual.* Australia, McGraw-Hill, 1969.
Webster, F.V. and Blackmore, F.C. 'Improving Road Capacity', in *Science Journal,* vol. 4, no. 8, Aug. 1968. pp. 69–74.

You can check your answers to some questions by turning to page 108.

OPTION

6

Who plans traffic flow? Who sorts out traffic problems? This option describes how a particular traffic problem was tackled. You may be able to investigate a problem in your own area.

Traffic Engineers

Traffic planners try to ensure that vehicles and pedestrians can move safely from one point to another in the least possible time.

Usually a traffic engineer is qualified in civil engineering and has completed post-graduate studies in traffic engineering. Electrical engineering qualifications are helpful, too, as smooth flow of traffic often depends upon the effective use of traffic signals and, sometimes, computers, radio or television.

A motorist reporting a traffic problem.

The traffic engineer has assistants to help him make surveys and plan the solutions to problems. They may be qualified draughtsmen.

He must also work closely with many other organizations such as road planning authorities and safety councils.

Engineers who are in charge of traffic engineering departments of city councils spend much of their time listening to telephoned complaints. Sometimes reports come to them from councillors or members of their own departments who are familiar with traffic patterns along the main roads and who are quick to notice when problems are developing.

As not enough money is ever available to tackle all of them at once, problem areas are listed in order of priority.

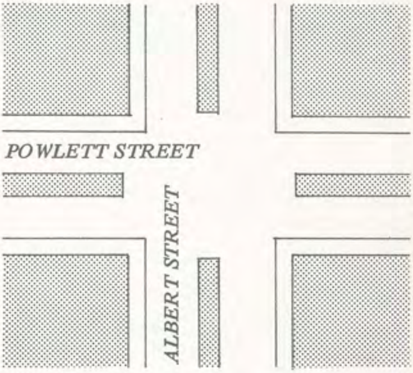
A PROBLEM FOR SOME TRAFFIC ENGINEERS–AND A SOLUTION

Powlett Street and Albert Street intersect at right angles, but the heavy traffic in Albert Street made it difficult for vehicles using Powlett Street to enter this intersection. Drivers of vehicles in Powlett Street became impatient at long delays and tried to force their way across the intersection. This caused interruption to the traffic flow in Albert Street and sometimes resulted in collisions.

Irate motorists and concerned local residents reported accidents and delays to traffic authorities. Serious accidents were reported to the police.

The council traffic engineers met to discuss the large number of complaints and the reports they had received from the police. Maps of the immediate area were studied to help define the problem.

Traffic flow and traffic problems in surrounding areas were also considered.



Traffic at the intersection of Albert and Powlett Streets after traffic lights were installed but before they were operating.

Adjusting signal times.

Planning Action

The traffic engineers concluded that the installation of traffic lights at this intersection would improve safety and give smoother traffic flow.

They first had to obtain approval from the council and from the Road Safety and Traffic Authority. Next, calculations were done to determine the most suitable timing for the traffic lights.

Changing the Traffic Flow

Finally, traffic signals were installed and set in operation. The intersection was inspected often to see that traffic was flowing smoothly in all directions.

The signal timing was checked and adjusted to the timing of signals at other intersections nearby so that traffic could flow without undue delay. This was particularly important for Albert Street, which is used by far more vehicles than Powlett Street.

Measuring the Effect of the Change

A traffic count was then necessary to make sure that there were no unexpected effects from the installation of the traffic lights.

When taking such traffic counts, special officers are stationed at each corner of an intersection. Each officer holds a board fitted with three counters. He presses a lever on one counter whenever a car passes through the intersection. A second counter is used to count all vehicles making a right-hand turn and a third is used for traffic turning left.

A traffic officer making an intersection traffic count.

Has the Problem Been Sorted Out?

When the photo below was taken the lights were operating, and the traffic appeared to be moving freely without major hold-ups. However checks were still made from time to time to ensure that there were no undue delays at the intersection.

Traffic at the intersection of Albert and Powlett Streets after traffic lights began operating.

A TRAFFIC PROBLEM FOR YOU

There may be a traffic problem in your area which you could investigate. It could be at an intersection where there are often collisions or long delays, or at a place where pedestrians find it difficult to cross at certain times during the day. It could be the problem of a freeway dividing a community into two parts.

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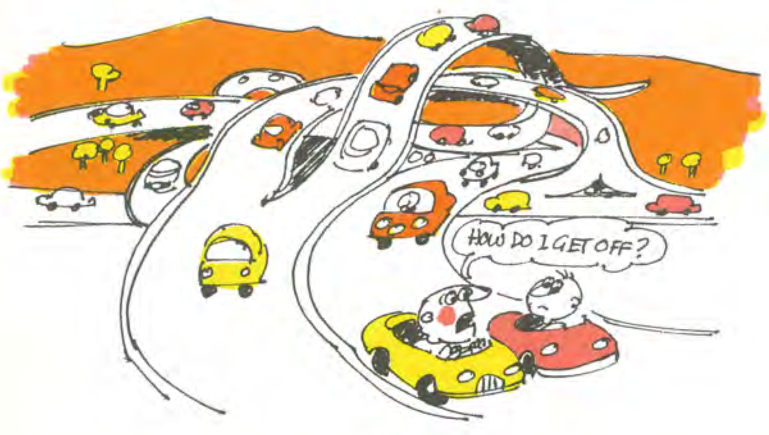

HOW DO I GET OFF?

OPTION

7

In an emergency a driver sometimes finds that his stopping distance is greater than he expected. He may even lose control of his vehicle. In this option you can use a cart to investigate possible causes of these hazards.

Skidding

'Drive carefully!' What should this warning mean to a driver? What is a safe driving speed on a dry, tar-sealed road may be dangerous on the same road when it is wet, or on an unsealed road. 'Safe driving' covers more than such things as skilful steering and the obeying of traffic rules. It also covers a knowledge of the effects of different road conditions on starting, steering and stopping a vehicle.

You know that friction is a force which opposes the motion of a vehicle. But friction is also essential for the control of a vehicle.

Braking too hard locks the wheels of a vehicle and this leads to loss of control. You can find out more about this in Activity 1.

ACTIVITY 1: LOCKED WHEELS

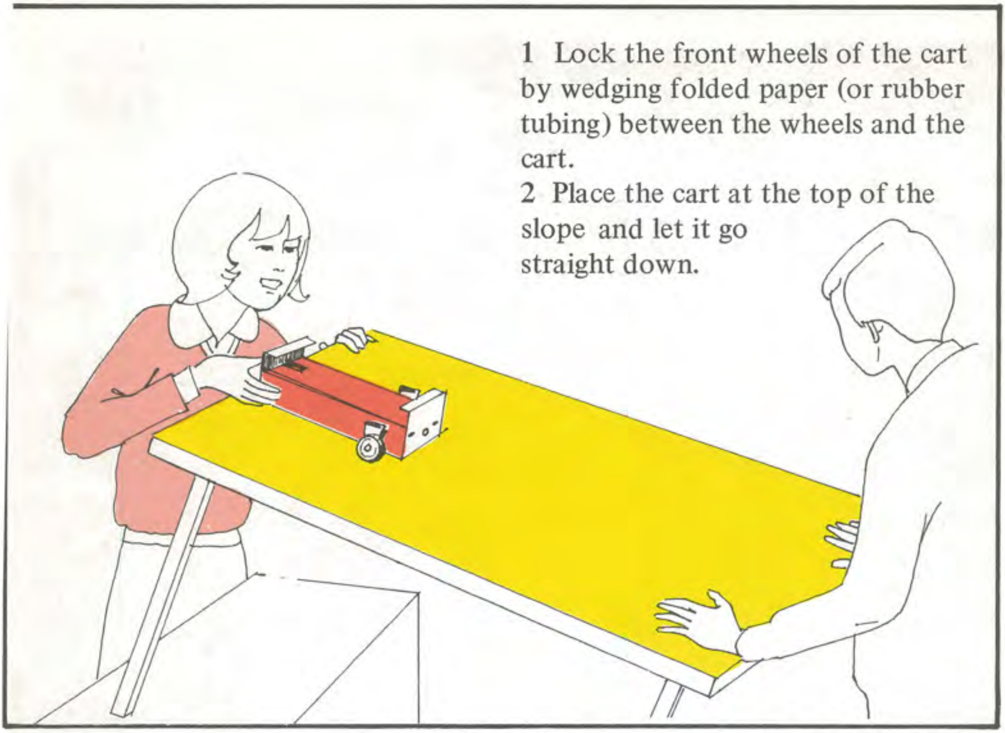
What happens to a car with locked wheels? You can use a cart to find out for yourself.

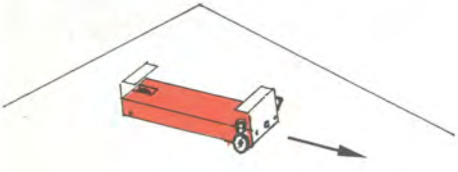
You will need:

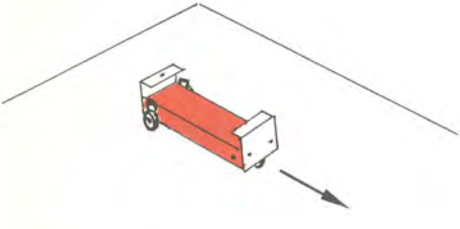
- 1 cart (or toy car)
- small pieces of paper (or bits of rubber tubing)
- 1 table, about 1.5 m long, which can be raised at one end.

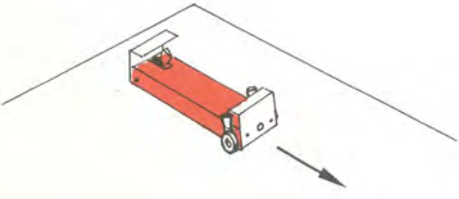
1 Lock the front wheels of the cart by wedging folded paper (or rubber tubing) between the wheels and the cart.

2 Place the cart at the top of the slope and let it go straight down.









3 Repeat, but this time try to run it at a slight angle down the board. Notice how well the cart maintains its direction.

4 Now reverse the cart so that the front wheels become the 'rear wheels' and repeat steps 2 and 3.

5 Lock all the wheels and repeat steps 2 and 3 again.

You may need to repeat the whole activity several times, and you may need to use a slope that is longer, steeper, or more slippery.

✍ 7.1 Report your findings under the headings: Front Wheels Locked; Rear Wheels Locked; All Wheels Locked.

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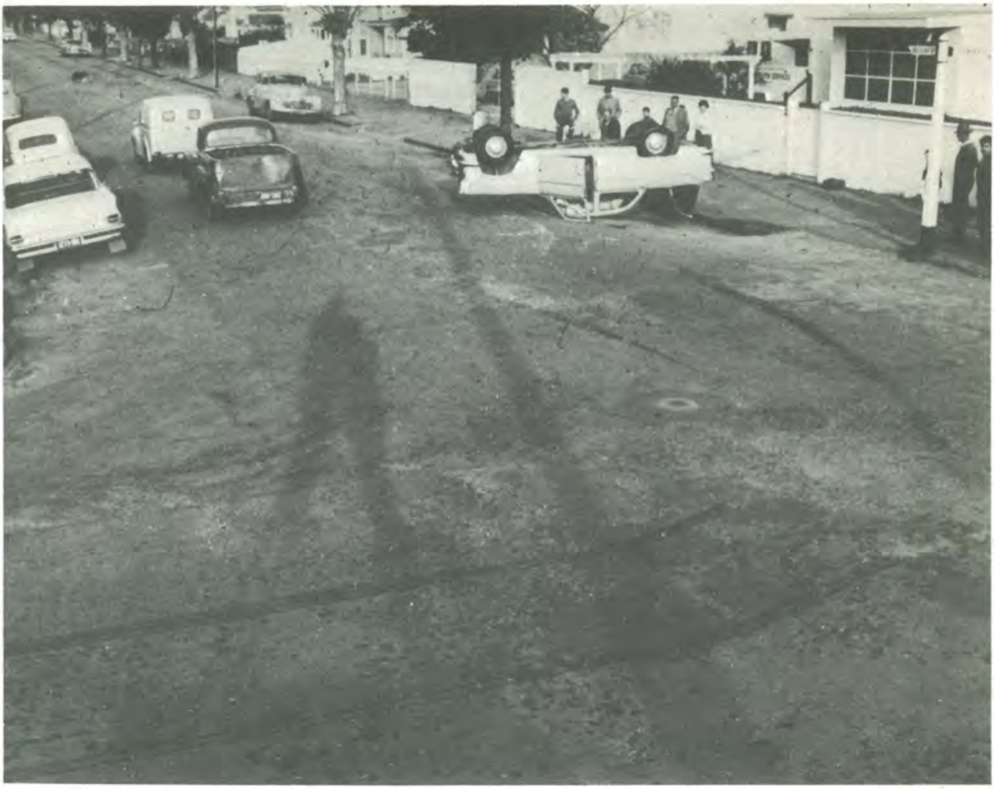
Activity 1 continued next page



Locked wheels caused these skid marks.
(Photo from Traffic Accidents in Adelaide, South Australia. *Australian Road Research Board Special Report No. 1–1966 Figure 10.7.)*

Car designers have tried a number of ways to solve the problem of loss of directional control caused by locked rear wheels.

In some cars, the front brakes are designed to apply a greater retarding force than the rear.

This can be done by using disc brakes on the front wheels and drum brakes on the rear.

Sometimes two separate (dual) braking systems are used. This ensures that a greater force is applied to the front wheels.

Other cars are equipped with anti-locking devices which release the braking force from the rear wheels before they can lock.

You could try to find out in which cars these methods are used.

Also, you could design experimental cars to see how they perform with locked wheels. Using plastic building blocks and wheels, you could build cars of almost any shape or size. A few things you may want to investigate are listed opposite.

Yes, that's right!! I did say the engine was missing. Look!!

☐ Does it make any difference whether the engine of the car is at the front or the rear?

He was right behind me when we braked suddenly

☐ Does it make a difference if the main mass of the car is higher up or closer to the ground?

He's the director of the tyre company

☐ What effect does adding an extra set of wheels have, if the rear wheels are locked?

☐ Can you show how a semi-trailer can jack-knife?

He ought to read 'Traffic' and learn why trucks jack-knife.

Sliding wheels result in many accidents. In the next activity you can investigate why rolling wheels are safer.

ACTIVITY 2:
STATIC AND SLIDING FRICTION

Although friction is a force which opposes starting and moving, it is essential for controlling the starting, stopping and steering of vehicles. A driver who understands friction forces can understand how best to handle his vehicle.

You can use the cart again to represent a car.

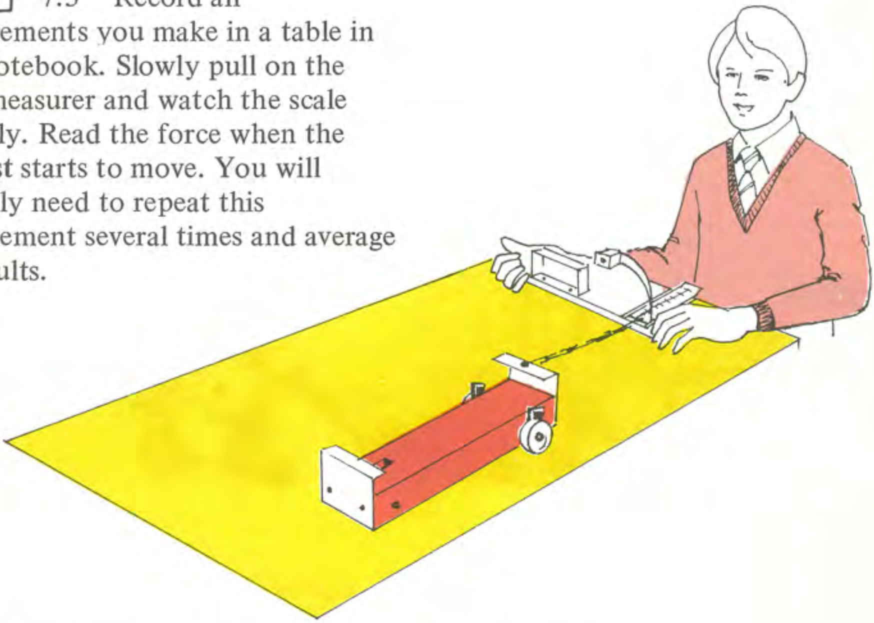
You will need:
- 1 cart
- 1 force-measurer, 0–10 N (or a 0–10 N spring balance)
- small pieces of paper (or bits of rubber tubing)
- paper-clips.

TO MEASURE STATIC (NO MOTION) FRICTION

First, assume the car is stationary, with the brakes on. You can prevent the cart wheels from turning by wedging them as before.

Attach the force-measurer to the cart (using bent paper-clips as shown).

✍ 7.3 Record all measurements you make in a table in your notebook. Slowly pull on the force-measurer and watch the scale carefully. Read the force when the cart **just** starts to move. You will probably need to repeat this measurement several times and average the results.



The force you record is a measure of static friction.

TO MEASURE SLIDING FRICTION

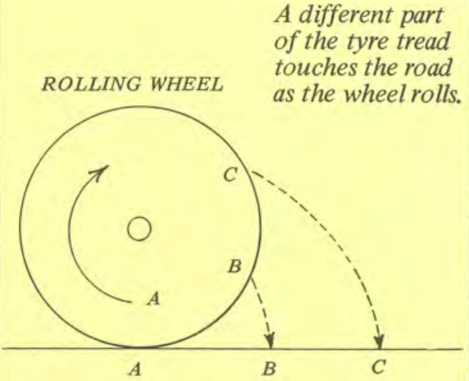
To measure sliding friction, repeat the activity again, but this time keep pulling the cart slowly after it starts to move.

7.4 Measure the force needed to keep the cart moving. You can do this by watching the reading on the force-measurer scale whenever the cart is about to stop. Record your readings and compare them with the results for static friction.

FRICTION AND SAFETY

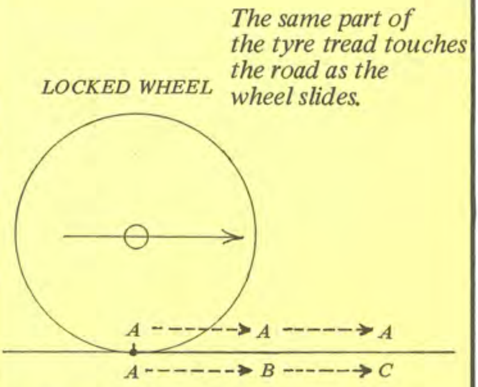
It may surprise you to learn of the important part **static friction** plays in holding the tyre on the road when a wheel rolls. As a wheel rolls, another part of the tread comes into contact with a different part of the road. The wheel does not slide.

When a wheel locks or slides sideways the same part of the tyre tread slides along the road. The force in this case is **sliding friction,** which you probably found was less than static friction.



A different part of the tyre tread touches the road as the wheel rolls.

STATIC FRICTION
THE WHEEL ROLLS ON THE ROAD SURFACE.



The same part of the tyre tread touches the road as the wheel slides.

SLIDING FRICTION
THE WHEEL SLIDES ALONG THE ROAD.

Activity 2 continued next page

Static friction enables the wheels of a car to grip the road (when force is applied). You may have experienced the spinning of wheels on wet grass where there is very little friction. Static friction also stops the wheels from slipping when the brakes are applied. It also stops them from sliding sideways when rounding a curve.

But there is a limit to the force of static friction. If you apply too much force when starting, or if you round a corner too fast, slipping will occur.

Now you can see why skidding is so dangerous. Instead of the static friction between tyres and road slowing down the rolling wheels over a short distance, the smaller sliding friction leads to a longer stopping distance. Furthermore, when the rear wheels are locked, steering control is lost.

Whenever wheels lock and skid the first thing to do is to stop braking. This allows the wheels to start rolling again. Then the brakes can be reapplied and the larger static friction force will help stop the car. A skilled driver knows just how hard to brake without locking the wheels.

For safety and traction, static friction between the tyres of a car and the road should be large. In the next activity you can investigate methods of increasing static friction.

ACTIVITY 3: FRICTION, WEIGHT, AND TYPE OF SURFACE

You will need:
- the equipment from Activity 2
- 50 N force-measurer blade
- 2 bricks (or similar masses).

WEIGHT

How does the weight of the cart affect static friction? To try to find out, you can change the weight of the cart by placing bricks or other masses on it.

Be sure to pull the cart very slowly and carefully so that you measure static friction each time.

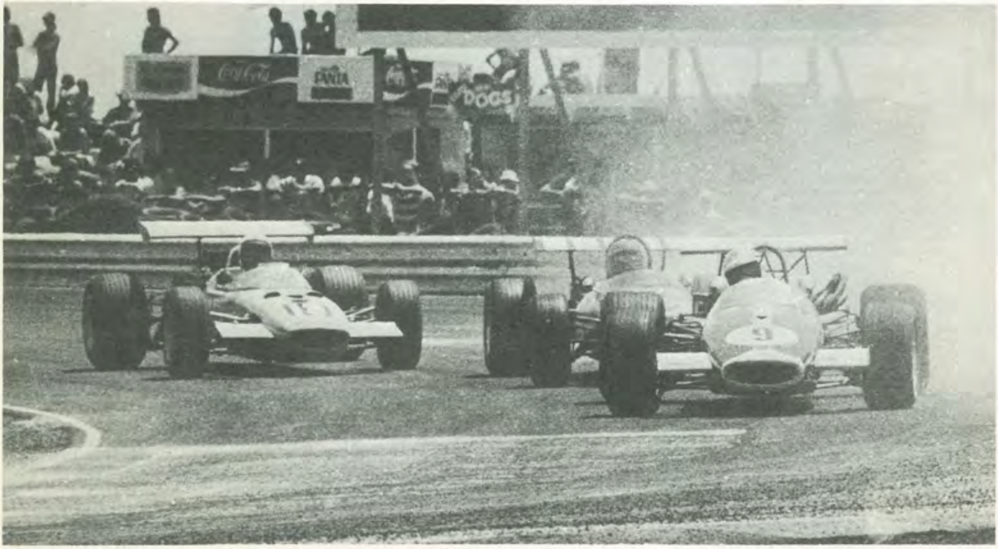
✍ 7.5 Record the static friction and the weight of the cart for each measurement in a table.

✍ 7.6 Use your results to help you answer the following questions:

☐ When is a semi-trailer most likely to skid? When it is fully loaded or empty? Give a reason for your answer.

☐ Why does a car with a moderate load often 'hold the road' better than an unloaded car?

☐ Why do some racing cars have an aerofoil over the rear wheels?



This photo shows racing cars with aerofoils over rear wheels.

Activity 3 continued next page

TYPE OF SURFACE

How does the type of surface affect friction? To test this, you could cover the table surface with different substances, e.g. water, oil, sand. Or you could pull the cart over different surfaces, e.g. glass, bitumen, concrete, hardboard. You could even change the surface of the cart wheels, e.g. cover them with adhesive tape, or place rubber bands around them.

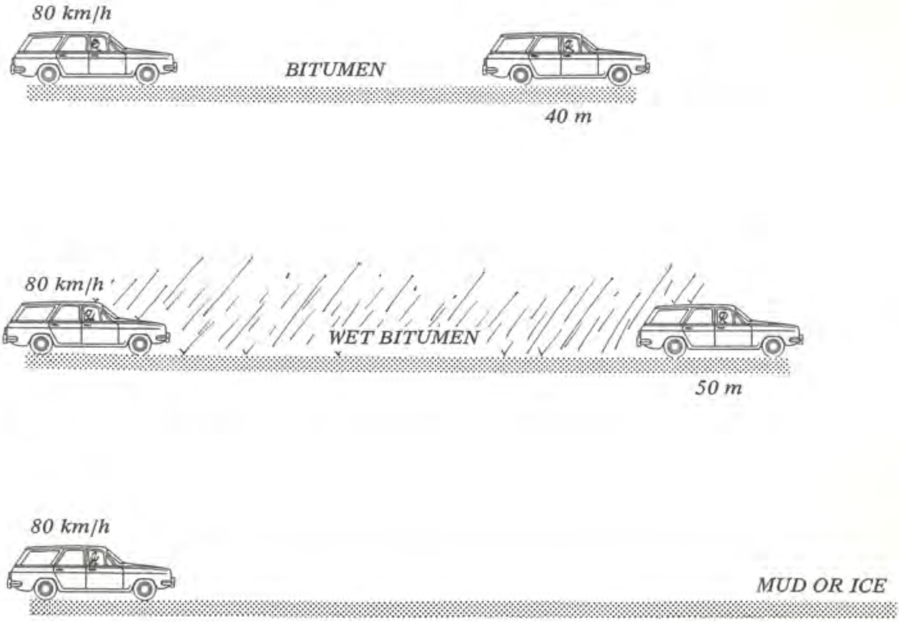
It is difficult to predict what the friction force between two surfaces will be.

To show the size of the friction between two surfaces a number called the **coefficient of friction** is used. Listed below are the coefficients of static friction for rubber car tyres (in good condition) on various road surfaces.

SURFACE	COEFFICIENT OF FRICTION WITH RUBBER CAR TYRES*
CONCRETE	0.90
BITUMEN	0.85
BITUMEN (wet)	0.65
GRAVEL	0.65
SNOW	0.45
MUD OR ICE	0.25

*** These coefficients decrease slightly with speed, particularly for a wet surface. There will also be considerable variation due to factors such as road wear, temperature (e.g. ice) and road base (e.g. mud).**

BRAKING DISTANCES UNDER DIFFERENT DRIVING CONDITIONS



Any surface such as concrete which has a high coefficient of friction provides a very good grip for tyres, while mud, which has a low coefficient, provides a poor grip (little friction).

The coefficient of friction is calculated using the formula:

$$\text{coefficient of friction} = \frac{\text{applied force}}{\text{weight}}$$

You could perhaps test a rubber-tyred vehicle of some sort, e.g. a toy car, on various surfaces.

If you have done Option 4 (Stop!), you will have found out something about braking distances. The values given there were for a dry, sealed road. For other surfaces these braking distances can be quite different.

Consider a car (in good condition) travelling at 80 kilometres per hour. On a dry sealed road, the braking distance would be about 40 metres. (Of course the total stopping distance would be greater than this.) After a shower of rain, the braking distance could be as great as 50 metres. If there were mud or ice on the road this distance could be as great as 125 metres.

A driver should know how road conditions affect braking distances, and drive to suit the conditions.

You may like to discuss with others what effect a bumpy surface would have on the coefficient of friction.

The next activity will give you some further information about safe driving.

ACTIVITY 4: LUBRICATION

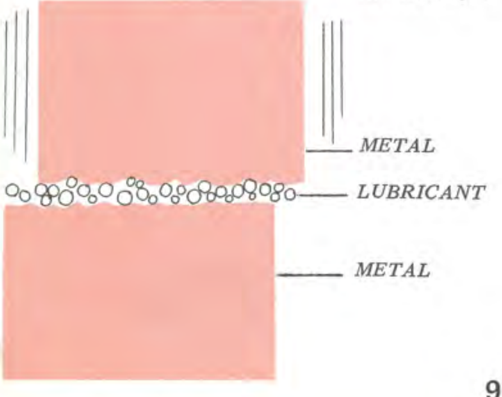
You have found that friction is essential for keeping a car safely on the road, but friction is a nuisance in the moving parts of engines and machines because it causes heating and wear and tear.

If metal rubs on metal, the surfaces get very hot. The metals then expand. If this happens in a car engine, the pistons (which move up and down in the cylinders) expand. The pistons then fit too tightly. A motor can 'seize' if this happens, because the pistons can't move.

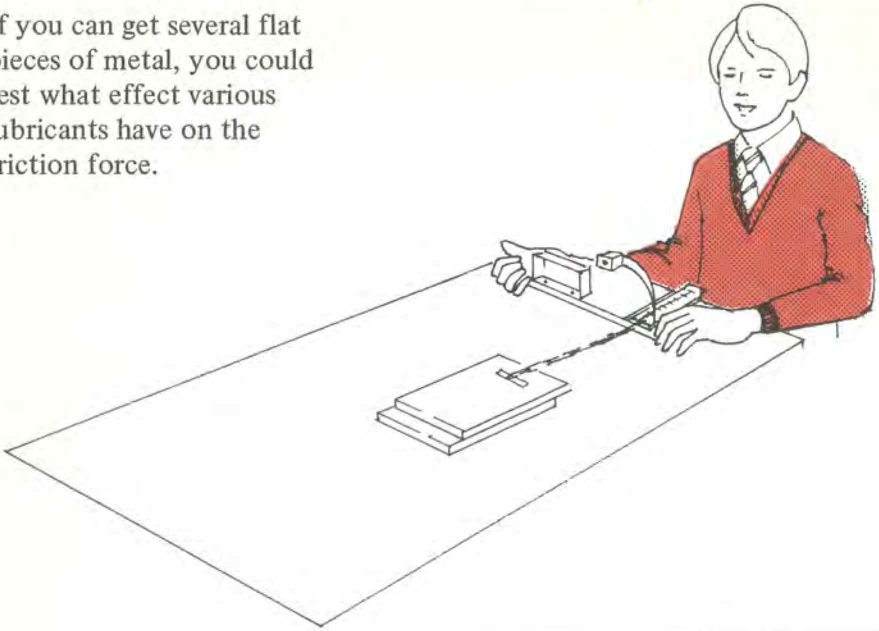
Most surfaces that rub together must be protected by **lubricants**–substances such as oil and grease which reduce friction. Listed below are some coefficients of friction to show how lubricants reduce friction.

SURFACES	COEFFICIENT OF FRICTION
STEEL–STEEL	0.58
STEEL–STEEL (lubricated with light machine oil)	0.16
STEEL–STEEL (lubricated with thick gear oil)	0.12

Not all substances which rub together need lubricants. For example, because friction between two Teflon surfaces is very low, no lubricant is necessary where they rub.



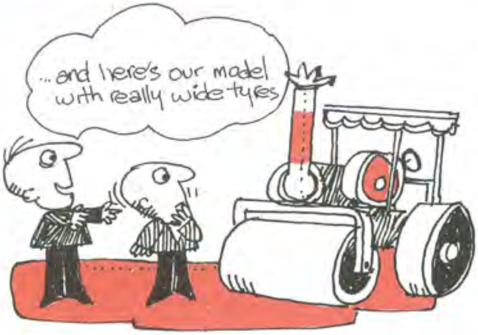
If you can get several flat pieces of metal, you could test what effect various lubricants have on the friction force.



The lubricant sticks to the metal surfaces, and in moving parts of engines and machines the lubricant layers glide over each other. At low temperatures the sticking forces between the lubricant layers themselves can be quite large, but these forces decrease with increase in temperature. A lubricant is designed to be used at a particular temperature. **Additives** enable lubricants to be used over a wide range of temperatures.

Another method of reducing friction makes use of the fact that **rolling friction** is much less than **sliding friction**. Just as the ancient Egyptians used rollers to reduce friction between enormous blocks of stone and the ground, **ball-bearings** or **roller-bearings** can be used to reduce friction between metal surfaces. The wheels of the cart you have been using rotate very easily because there are ball bearings between the wheels and the axles. Bicycle wheels also run on ball bearings. Most car wheels have roller bearings. However, bearings still need to be lubricated.

FURTHER ACTIVITIES


...and here's our model with really wide tyres

You may want to design your own tests, read books or pamphlets, or interview various people.

There are a few suggestions below.

✍ 7.7 Make notes about whatever you find out so that you can make your report.

☐ Using a bicycle, you could compare braking distances on various surfaces. To do this, you would have to make sure that the bicycle was always travelling at the same speed when the brakes were applied. (See Option 4, page 62.)

☐ Are wide tyres (including radial tyres) any better than ordinary tyres? If so, why? You could perhaps get information from racing car drivers or tyre manufacturers.

☐ What is the purpose of the tread on a tyre? Does the tread serve any special purpose on a wet road? What is aquaplaning?

☐ What is the difference between drum brakes and disc brakes? Which type is better? What causes 'brake fade'?

You can check your answers to some questions by turning to page 108.

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HOW DO I GET OFF?

OPTION

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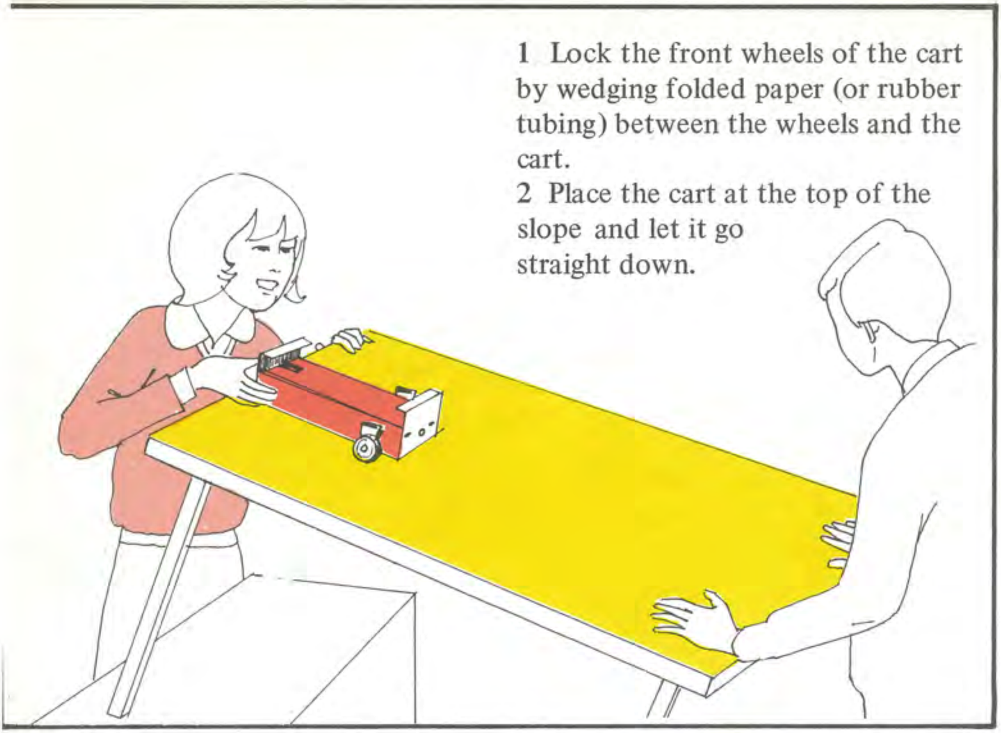
But officer– my steering failed



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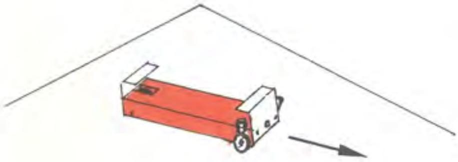

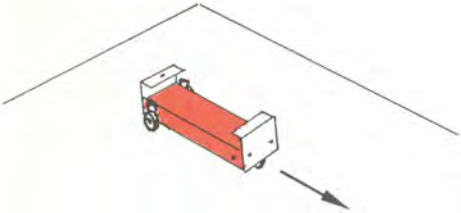

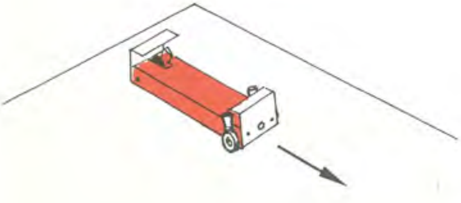

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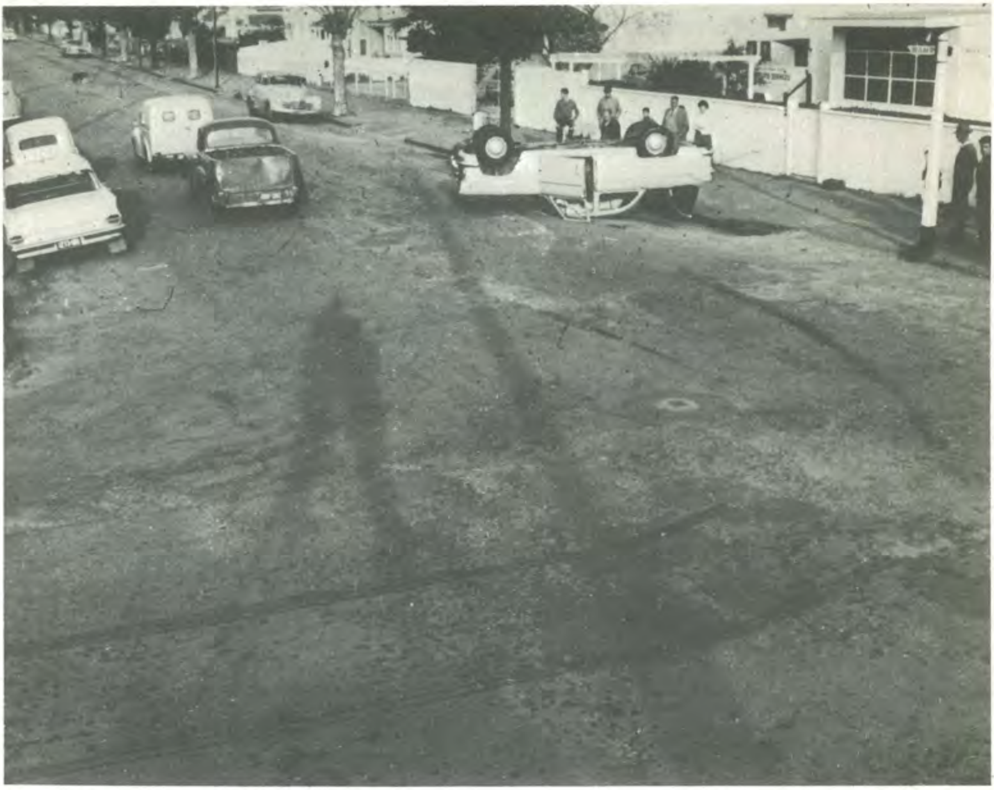
Activity 1 continued next page



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(Photo from Traffic Accidents in Adelaide, South Australia. *Australian Road Research Board Special Report No. 1–1966 Figure 10.7.)*

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Other cars are equipped with anti-locking devices which release the braking force from the rear wheels before they can lock.

You could try to find out in which cars these methods are used.

Also, you could design experimenta cars to see how they perform with locked wheels. Using plastic building blocks and wheels, you could build cars of almost any shape or size. A few things you may want to investigate are listed opposite.

Yes, that's right!! I did say the engine was missing. Look!!

☐ Does it make any difference whether the engine of the car is at the front or the rear?

He was right behind me when we braked suddenly

☐ Does it make a difference if the main mass of the car is higher up or closer to the ground?

He's the director of the tyre company

☐ What effect does adding an extra set of wheels have, if the rear wheels are locked?

☐ Can you show how a semi-trailer can jack-knife?

He ought to read 'Traffic' and learn why trucks jack-knife.

Sliding wheels result in many accidents. In the next activity you can investigate why rolling wheels are safer.

ACTIVITY 2:
STATIC AND SLIDING FRICTION

Although friction is a force which opposes starting and moving, it is essential for controlling the starting, stopping and steering of vehicles. A driver who understands friction forces can understand how best to handle his vehicle.

You can use the cart again to represent a car.

You will need:

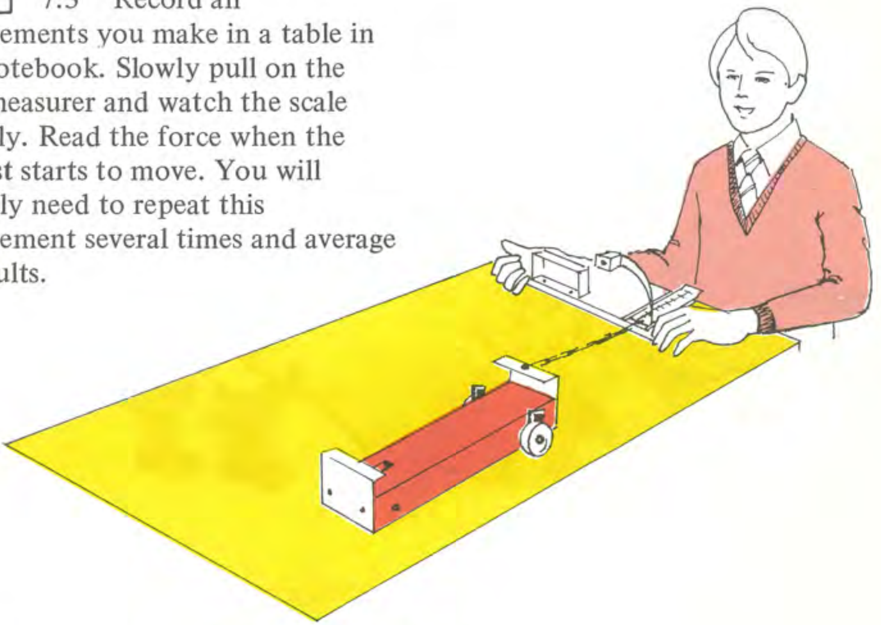
- 1 cart
- 1 force-measurer, 0–10 N (or a 0–10 N spring balance)
- small pieces of paper (or bits of rubber tubing)
- paper-clips.

TO MEASURE STATIC (NO MOTION) FRICTION

First, assume the car is stationary, with the brakes on. You can prevent the cart wheels from turning by wedging them as before.

Attach the force-measurer to the cart (using bent paper-clips as shown).

7.3 Record all measurements you make in a table in your notebook. Slowly pull on the force-measurer and watch the scale carefully. Read the force when the cart **just** starts to move. You will probably need to repeat this measurement several times and average the results.



The force you record is a measure of static friction.

TO MEASURE SLIDING FRICTION

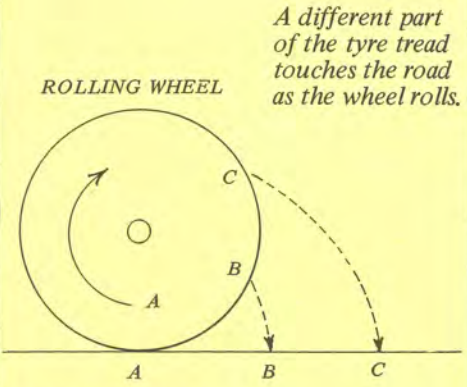
To measure sliding friction, repeat the activity again, but this time keep pulling the cart slowly after it starts to move.

7.4 Measure the force needed to keep the cart moving. You can do this by watching the reading on the force-measurer scale whenever the cart is about to stop. Record your readings and compare them with the results for static friction.

FRICTION AND SAFETY

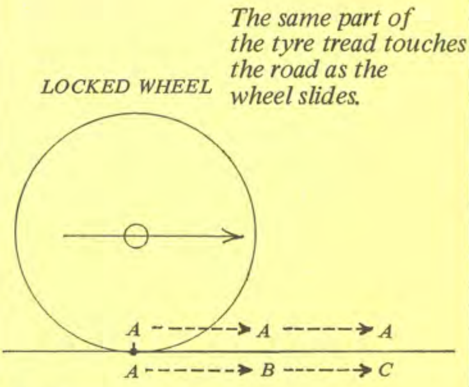
It may surprise you to learn of the important part **static friction** plays in holding the tyre on the road when a wheel rolls. As a wheel rolls, another part of the tread comes into contact with a different part of the road. The wheel does not slide.

When a wheel locks or slides sideways the same part of the tyre tread slides along the road. The force in this case is **sliding friction**, which you probably found was less than static friction.



A different part of the tyre tread touches the road as the wheel rolls.

STATIC FRICTION
THE WHEEL ROLLS ON THE ROAD SURFACE.



The same part of the tyre tread touches the road as the wheel slides.

SLIDING FRICTION
THE WHEEL SLIDES ALONG THE ROAD.

Activity 2 continued next page

Static friction enables the wheels of a car to grip the road (when force is applied). You may have experienced the spinning of wheels on wet grass where there is very little friction. Static friction also stops the wheels from slipping when the brakes are applied. It also stops them from sliding sideways when rounding a curve.

But there is a limit to the force of static friction. If you apply too much force when starting, or if you round a corner too fast, slipping will occur.

Now you can see why skidding is so dangerous. Instead of the static friction between tyres and road slowing down the rolling wheels over a short distance, the smaller sliding friction leads to a longer stopping distance. Furthermore, when the rear wheels are locked, steering control is lost.

Whenever wheels lock and skid the first thing to do is to stop braking. This allows the wheels to start rolling again. Then the brakes can be reapplied and the larger static friction force will help stop the car. A skilled driver knows just how hard to brake without locking the wheels.

For safety and traction, static friction between the tyres of a car and the road should be large. In the next activity you can investigate methods of increasing static friction.

ACTIVITY 3: FRICTION, WEIGHT, AND TYPE OF SURFACE

You will need:

- the equipment from Activity 2
- 50 N force-measurer blade
- 2 bricks (or similar masses).

WEIGHT

How does the weight of the cart affect static friction? To try to find out, you can change the weight of the cart by placing bricks or other masses on it.

Be sure to pull the cart very slowly and carefully so that you measure static friction each time.

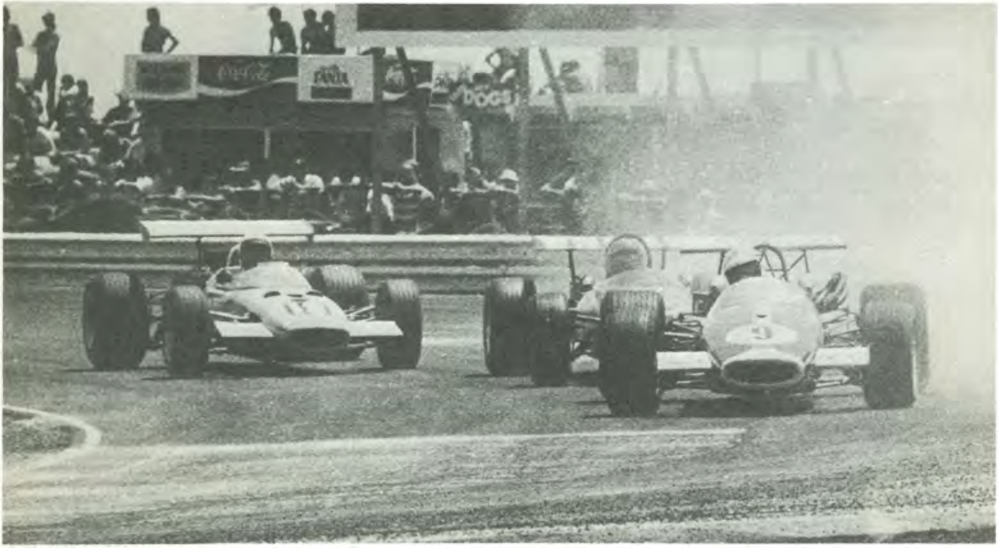
7.5 Record the static friction and the weight of the cart for each measurement in a table.

7.6 Use your results to help you answer the following questions:

☐ When is a semi-trailer most likely to skid? When it is fully loaded or empty? Give a reason for your answer.

☐ Why does a car with a moderate load often 'hold the road' better than an unloaded car?

☐ Why do some racing cars have an aerofoil over the rear wheels?



This photo shows racing cars with aerofoils over rear wheels.

Activity 3 continued next page

TYPE OF SURFACE

How does the type of surface affect friction? To test this, you could cover the table surface with different substances, e.g. water, oil, sand. Or you could pull the cart over different surfaces, e.g. glass, bitumen, concrete, hardboard. You could even change the surface of the cart wheels, e.g. cover them with adhesive tape, or place rubber bands around them.

It is difficult to predict what the friction force between two surfaces will be.

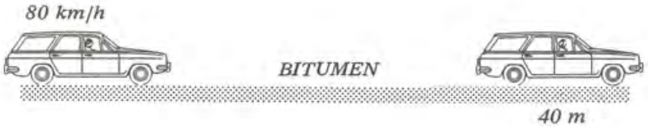
To show the size of the friction between two surfaces a number called the **coefficient of friction** is used.

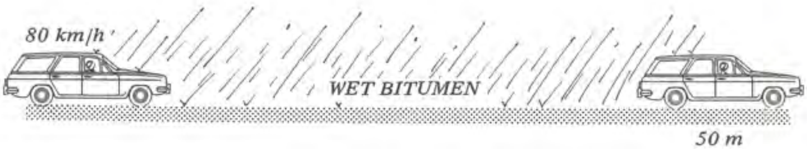
Listed below are the coefficients of static friction for rubber car tyres (in good condition) on various road surfaces.

SURFACE	COEFFICIENT OF FRICTION WITH RUBBER CAR TYRES*
CONCRETE	0.90
BITUMEN	0.85
BITUMEN (wet)	0.65
GRAVEL	0.65
SNOW	0.45
MUD OR ICE	0.25

*** These coefficients decrease slightly with speed, particularly for a wet surface. There will also be considerable variation due to factors such as road wear, temperature (e.g. ice) and road base (e.g. mud).**

BRAKING DISTANCES UNDER DIFFERENT DRIVING CONDITIONS





Any surface such as concrete which has a high coefficient of friction provides a very good grip for tyres, while mud, which has a low coefficient, provides a poor grip (little friction).

The coefficient of friction is calculated using the formula:

$$\text{coefficient of friction} = \frac{\text{applied force}}{\text{weight}}$$

You could perhaps test a rubber-tyred vehicle of some sort, e.g. a toy car, on various surfaces.

If you have done Option 4 (Stop!), you will have found out something about braking distances. The values given there were for a dry, sealed road. For other surfaces these braking distances can be quite different.

Consider a car (in good condition) travelling at 80 kilometres per hour. On a dry sealed road, the braking distance would be about 40 metres. (Of course the total stopping distance would be greater than this.) After a shower of rain, the braking distance could be as great as 50 metres. If there were mud or ice on the road this distance could be as great as 125 metres.

A driver should know how road conditions affect braking distances, and drive to suit the conditions.

You may like to discuss with others what effect a bumpy surface would have on the coefficient of friction.

The next activity will give you some further information about safe driving.

125 m

ACTIVITY 4: LUBRICATION

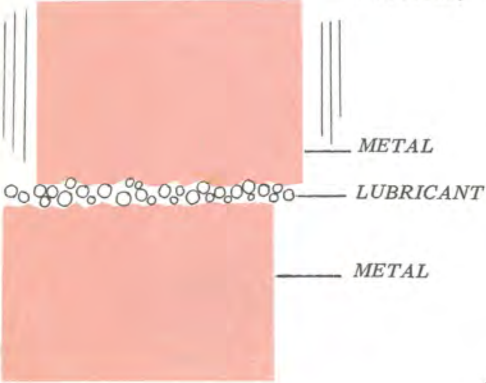
You have found that friction is essential for keeping a car safely on the road, but friction is a nuisance in the moving parts of engines and machines because it causes heating and wear and tear.

If metal rubs on metal, the surfaces get very hot. The metals then expand. If this happens in a car engine, the pistons (which move up and down in the cylinders) expand. The pistons then fit too tightly. A motor can 'seize' if this happens, because the pistons can't move.

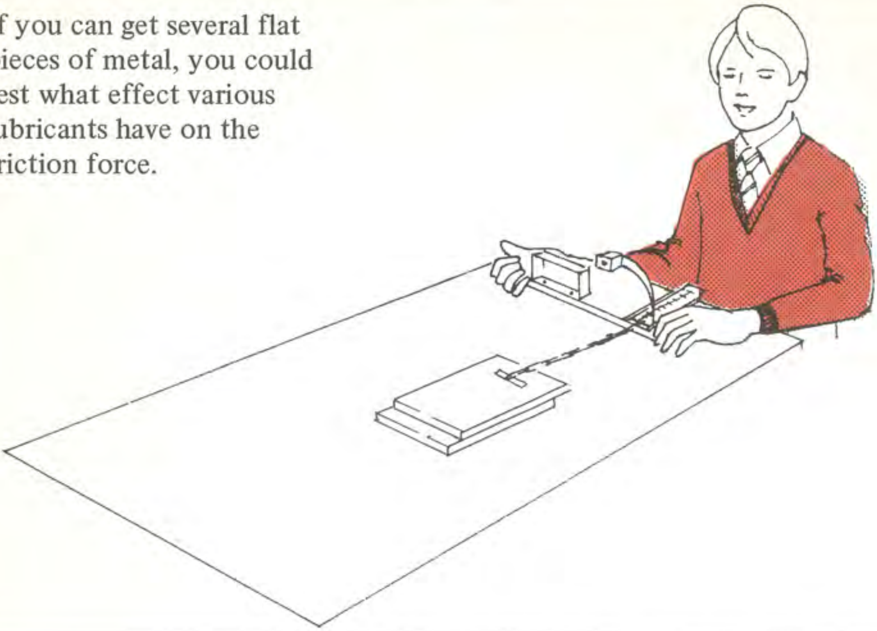
Most surfaces that rub together must be protected by **lubricants**–substances such as oil and grease which reduce friction. Listed below are some coefficients of friction to show how lubricants reduce friction.

SURFACES	COEFFICIENT OF FRICTION
STEEL–STEEL	0.58
STEEL–STEEL (lubricated with light machine oil)	0.16
STEEL–STEEL (lubricated with thick gear oil)	0.12

Not all substances which rub together need lubricants. For example, because friction between two Teflon surfaces is very low, no lubricant is necessary where they rub.



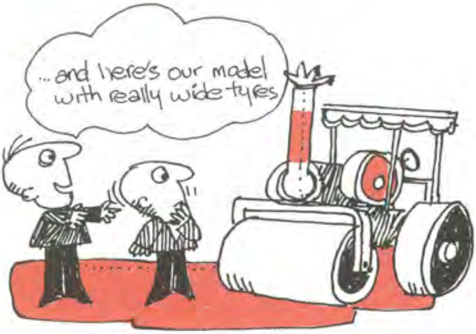
If you can get several flat pieces of metal, you could test what effect various lubricants have on the friction force.



The lubricant sticks to the metal surfaces, and in moving parts of engines and machines the lubricant layers glide over each other. At low temperatures the sticking forces between the lubricant layers themselves can be quite large, but these forces decrease with increase in temperature. A lubricant is designed to be used at a particular temperature. **Additives** enable lubricants to be used over a wide range of temperatures.

Another method of reducing friction makes use of the fact that **rolling friction** is much less than **sliding friction.** Just as the ancient Egyptians used rollers to reduce friction between enormous blocks of stone and the ground, **ball-bearings** or **roller-bearings** can be used to reduce friction between metal surfaces. The wheels of the cart you have been using rotate very easily because there are ball bearings between the wheels and the axles. Bicycle wheels also run on ball bearings. Most car wheels have roller bearings. However, bearings still need to be lubricated.

FURTHER ACTIVITIES


...and here's our model with really wide tyres

You may want to design your own tests, read books or pamphlets, or interview various people.

There are a few suggestions below.

7.7 Make notes about whatever you find out so that you can make your report.

☐ Using a bicycle, you could compare braking distances on various surfaces. To do this, you would have to make sure that the bicycle was always travelling at the same speed when the brakes were applied. (See Option 4, page 62.)

☐ Are wide tyres (including radial tyres) any better than ordinary tyres? If so, why? You could perhaps get information from racing car drivers or tyre manufacturers.

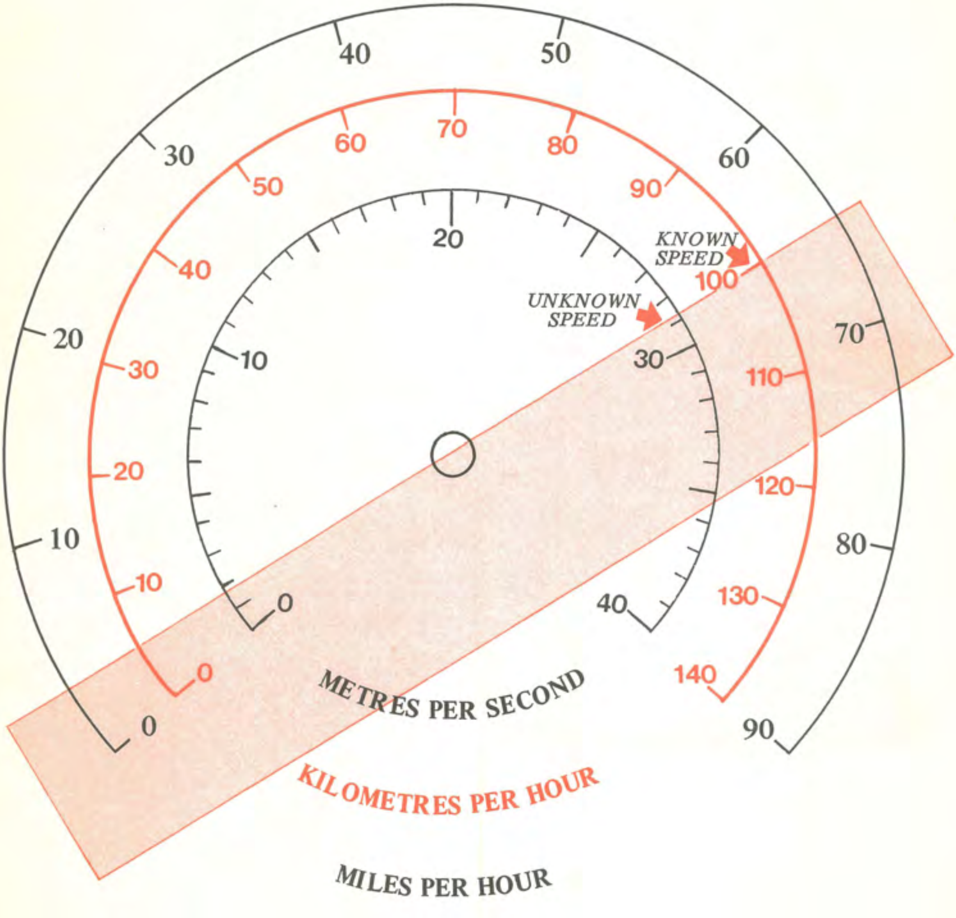
☐ What is the purpose of the tread on a tyre? Does the tread serve any special purpose on a wet road? What is aquaplaning?

☐ What is the difference between drum brakes and disc brakes? Which type is better? What causes 'brake fade'?

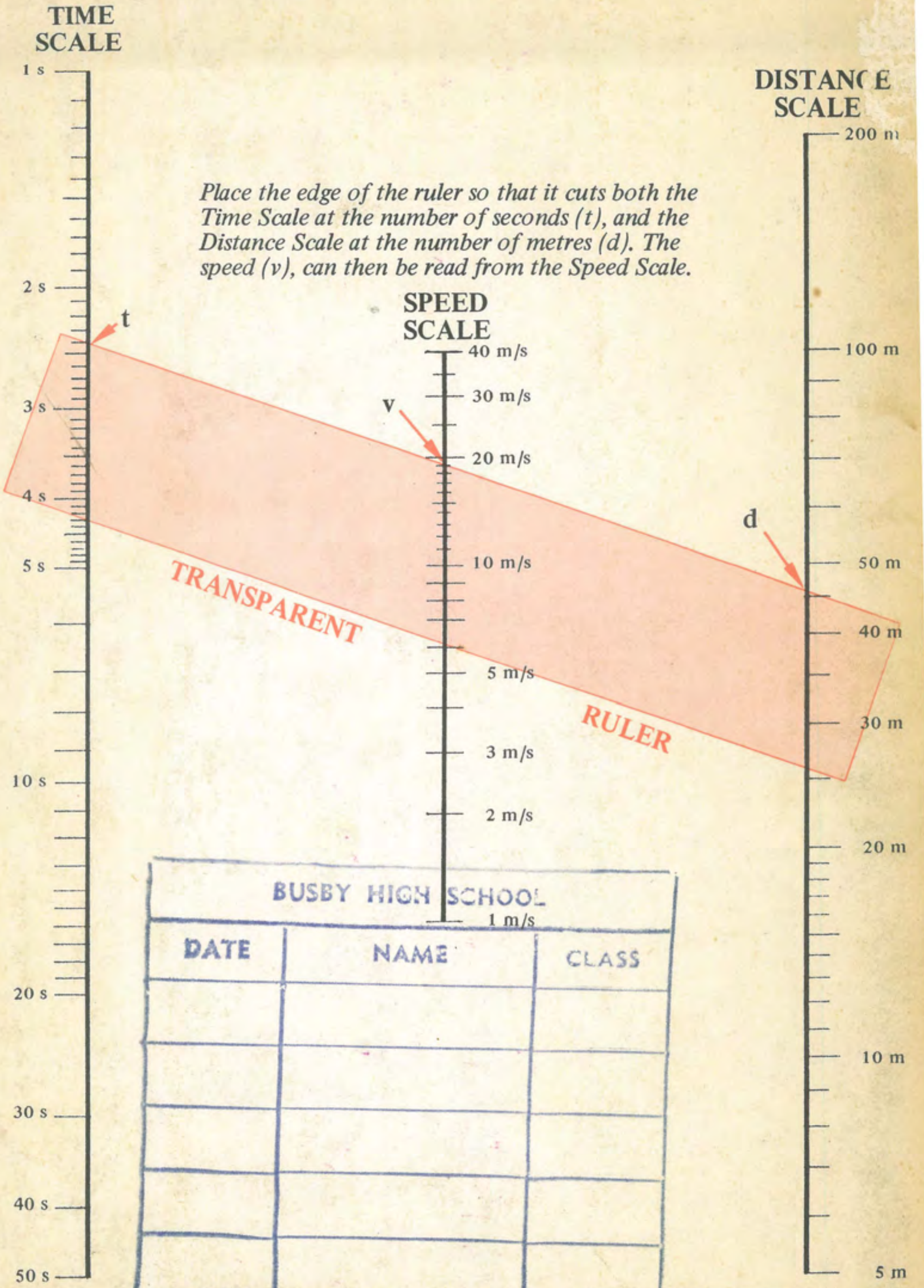
You can check your answers to some questions by turning to page 108.

SPEED CONVERSION CHART

Place the edge of the ruler so that it cuts the centre and the known speed on one scale. Then read off the speed from the other scale.



SPEED CALCULATOR



Place the edge of the ruler so that it cuts both the Time Scale at the number of seconds (t), and the Distance Scale at the number of metres (d). The speed (v), can then be read from the Speed Scale.

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